ONTARIO

DEPARTMENT OF LABOUR

MINISTER

THE HONOURABLE CHARLES DALEY

A Beginner's Book on Power Plant Operation

OPERATING ENGINEERS BOARD

TORONTO
Printed by BAPTIST JOHNSTON, Printer to the King's Most Excellent Majesty
1949

A BEGINNER'S BOOK ON POWER PLANT OPERATION

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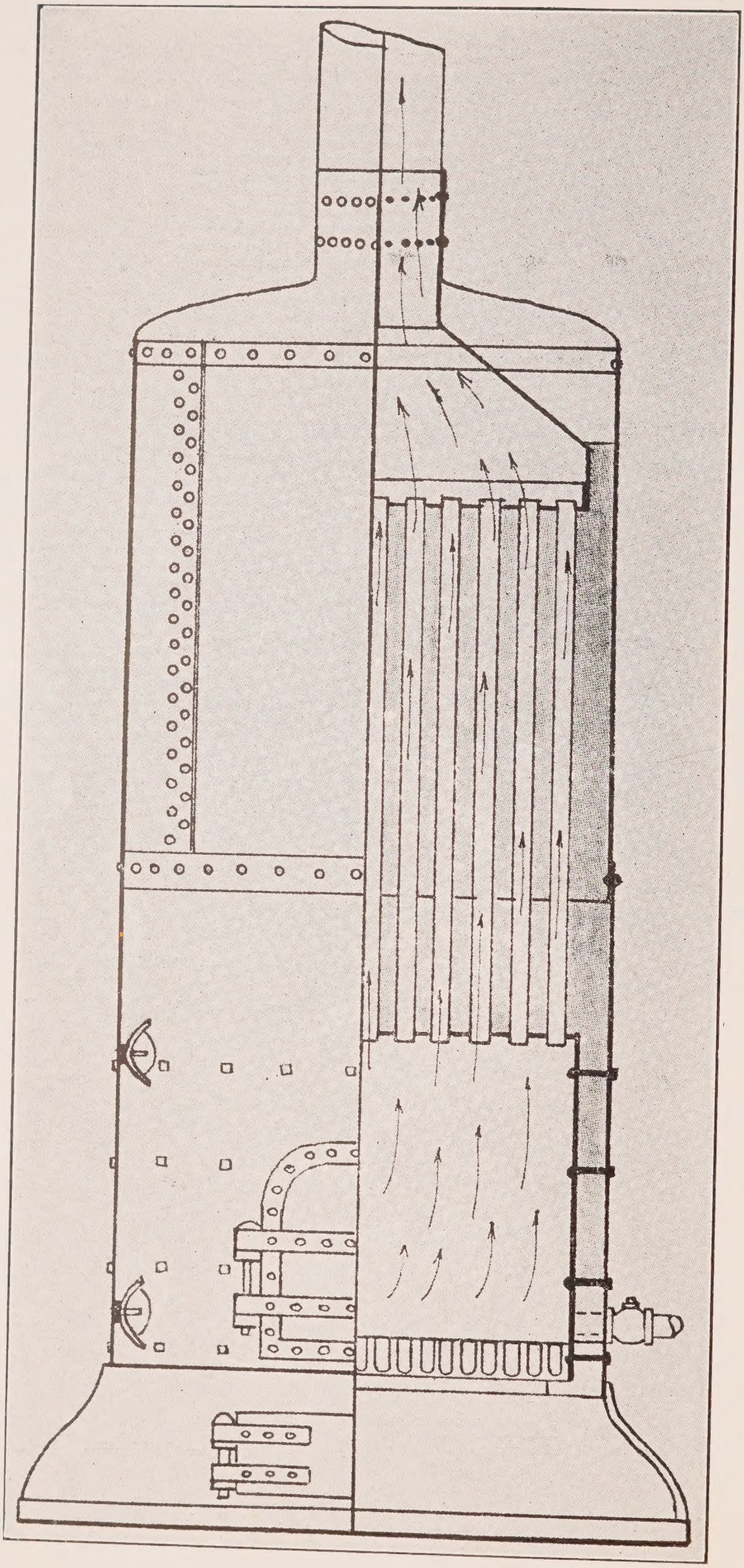

Vertical Fire Tube Boiler with submerged tubes.

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The East Block of the Ontario Parliament Buildings

FOREWORD

This elementary text book covering the subjects of Boilers, Engines, Pumps and Refrigeration is offered for the benefit of beginners in engineering and for those who may find the larger text books which we have compiled beyond their present capacity for study.

Merely the rudiments of the subjects treated are given, but it is hoped that the foundation which is laid in this book will be used by the readers as a stepping stone to higher and deeper engineering knowledge. Further study is made available in the larger text books compiled and issued by

The Board of Examiners,
Operating Engineers,
East Block, Parliament Buildings,
Toronto.

GETTING UP STEAM ON NEW BOILERS

If the boiler is new, or has been out of service for an extended period, or has been opened for cleaning or repairs, examine the inside of the boiler and make sure that it is free from tools and foreign matter and that there is no one in the boiler; then close the manhole openings.

Where a new boiler is to be placed in service the first time, it may be cleaned by boiling out with a mixture of soda ash and caustic soda. Fill the boiler with water to about the middle line of the water-glass, and add one part by weight of soda ash and one part caustic soda at a rate of 20 lbs. per 100 H.P. capacity. Dissolve the chemicals thoroughly before introducing into the water. Close the boiler and start a light fire, sufficient to carry 5 lbs. pressure in the boiler. Continue boiling two or three days. Empty the boiler and then wash thoroughly with fresh water.

See that the combustion chamber and gas passages are clean and in good repair, and that all clean-out doors in setting fit properly and are closed tight.

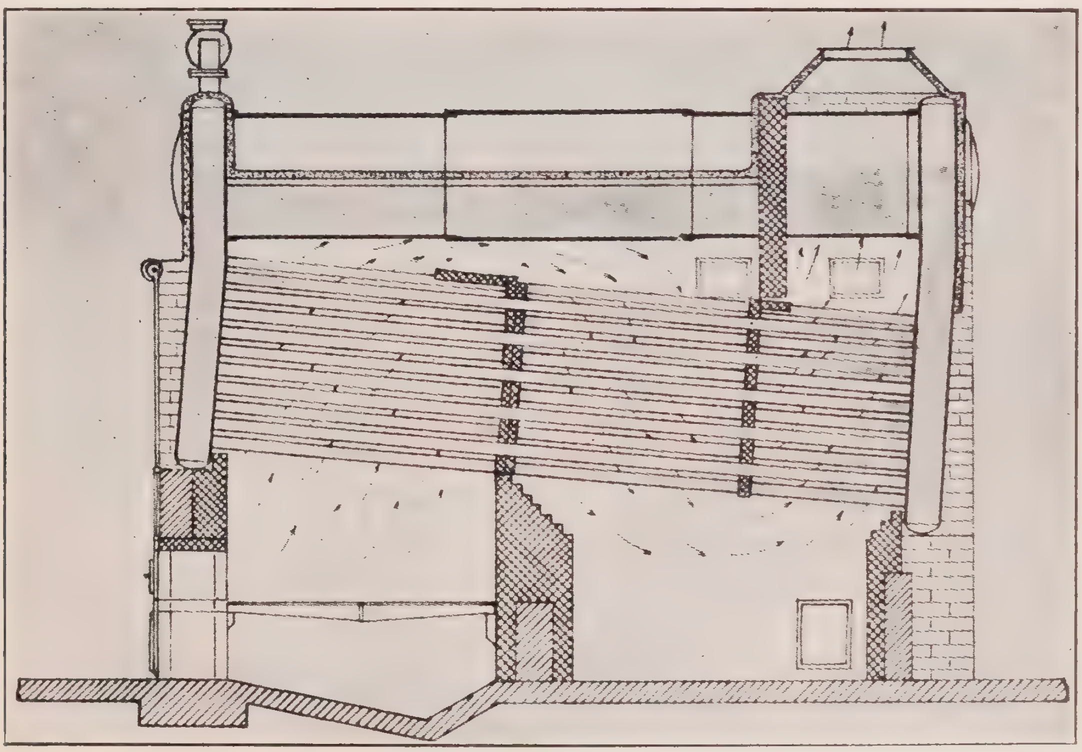


FIG. 1. Edge Morr Water Tube Boiler.

Operate both inlet damper and outlet damper, and make sure that they are free and in good condition. Leave the inlet and outlet dampers open. Operate the stoker and draft fan to see that they are ready for service. Make sure that the grates are satisfactory and in place.

See that the blow-off valves, water-column and water-glass drains, gauge cocks and feed valves are in good working condition and closed. Open a vent valve.

Fill the boiler with water to about half a glass position, and close feed connections. Where auxiliary feed connections are installed, they should be used in filling the boilers as a means of testing their condition. Open and close gauge cocks and blow-down valves on water-column and water-glass, in order to make sure that these connections are free and clear.

See that the cock on the steam-pressure gauge is open. Examine the safety valves as far as practicable to see that they are in working order.

Ease up on the stem of the main steam stop-valve, slightly lifting the valve off the seat in order to make sure that the valve is not stuck.

If coal is used as fuel, cover the grate with a thin layer of coal and start a light fire with live coals from adjacent boilers, or with wood or other light combustibles. Do not use any combustibles for igniting a coal fire in such a manner as to cause excessive smoke or possible flareback. Where pulverized coal, gas or oil is used as fuel, make sure that outlet damper is open to create a light draft before introducing and igniting fuel.

If oil is used as fuel, and the system is new or has been out of service for a considerable period, first clean and examine the strainers, clean and examine tips and burners. If compressed air is available, blow out the oil supply lines with air. Place and adjust burners and tips, and work the air registers to see that they are in good working condition. Close individual burner throttle valves. Test the steam coils in the heater for oil leakage by keeping the maximum allowable head of oil on the heater, with the steam-pressure shut off. Hold this head of oil on the heater in excess of 15 minutes. Next, unseat the steam-valve on the coil with the drip-valve wide open. Collect the condensate from the drip and examine for oil.

Remove any spilled oil about burners, fronts and floor, and see that there is no oil on the floor of the combustion chamber. Ventilate the boiler by opening draft gates and dampers.

If no steam is available for oil pump and burners, raise steam in boiler by wood fire. Remove any excess accumulation of water in the oil tank. See that oil pumps are warmed up ready for use and that relief-valves are properly set. Open suction-line valves and pump oil to burners. If oil lines are equipped with air chambers, charge them with compressed air. Examine oil lines and equipment for leaks.

Light the centre burner by holding a hand torch near and just under tip of burner, then turn on the oil and stand well clear to avoid possible flareback. If the torch is snuffed out before the oil is lighted, shut off the oil and relight the torch. Always use the torch for lighting burners until the brickwork is intensely hot, and even then if all burners are out. Next light the adjacent burners, but be sure that there is an excess of draft before lighting additional burners. Do not allow the oil to impinge excessively on the brickwork or parts of the boiler.

After lighting the fire, maintain a light fire until the brickwork of the setting is dried out thoroughly. If the entire setting is new, the drying out may require several days; if the lining of the combustion chamber only has been renewed, about 48 hours will be

sufficient time for drying out for small settings. Larger ones will require a longer time. After the usual week-end shutdown, a light fire should be carried about one hour. Only in extreme emergency should steam be raised in less than one-half hour, even with water-tube boilers.

Uneven heating of the setting will result in cracking the lining and setting, particularly in new brickwork, thereby destroying its value as an insulator and support. Uneven heating of the boiler will cause unequal expansion, resulting in distorted tubes and opening of seams, especially where the circulation of water may be sluggish, as in internally fired types of boilers.

After the water becomes heated, check the level of the water in the water-glass with gauge-cocks, and examine blow-off valves for leaks. After steam has escaped through a vent valve on the top of boiler for a few minutes, close the valve.

Cutting Boiler in on Line

In case a non-return valve is not used, the boiler stop-valve should, of course, be opened slowly when the pressure in the boiler and the steam-line are approximately equal. After opening the stop-valve, stand by for a short period, prepared to close the valve in case there is any indication of water hammer.

With one hand-operated stop-valve, and one combined stop and check-valve, when the hand-operated stop-valve is nearer the main header, open it slowly and preferably only a small amount at first. Stand by for short period to close the valve in case there is any indication of water-hammer, then open the valve to full opening. When the pressure of the boiler is still 10 to 50 lbs. below the pressure in the header, slowly back off the valve stem of the combined stop and check-valve sufficiently from the check to provide full opening of the check-valve. In order to insure that the check-valve functions properly, always use it automatically for cutting in and cutting out boilers, provided that the main header is filled with steam at full pressure.

Cleaning Fires

First, see that you have plenty of steam and water, then wing the live coal to one side and allow the other side to burn down as much as possible. When this is done, take slash bar or poker and get all the clinkers off the grates and scrape out with the ashes (if you have dump grates you can dump into the ash pan).

Wing live coal over to the side you have cleaned and fire lightly till you have fire in good shape, in the meantime allow the other side to burn down, and then clean it in the same manner. Then spread fire evenly over the whole grate, fire lightly and often until you get your fires bright and of the desired thickness.

Clean the fires when necessary, but preferably at stated periods and when boilers are operating at low rating, as at noon time and just before peak loads. Avoid holes in fire and excessive drafts while burning out the fire. Clean fires as rapidly as possible to minimize cold air in the boiler.

Banking Fires

See that you have plenty of water in the boiler and push all live coal into a heap and cover with green or slack coal. Some prefer pushing the coal to the back, and others near the front, but care should be taken that some of the grate space is bare. Shut the drafts so that there is no danger of the fire burning up too fast, but when fires are banked and the furnace temperature is reduced, make sure that enough air is carried through the furnace and boiler, to prevent the accumulation of combustible gases within the setting.

Removal of Soot and Ashes

Keep the tubes reasonably free from soot. When a lance or soot blower is used, drain the steam or air supply connections so that the steam or air is practically dry. After the boiler has been cooled, brush or scrape any hardened soot or deposit from the tubes.

Remove the ashes frequently and do not permit the accumulation of any large amount of ashes in the ashpit, boiler flues or base of chimney. Do not pile ashes against the boiler front, and when wetting down ashes, make sure that no water is thrown on hot castings. To avoid being scalded, stand well back from hot ashes or refuse while spraying water on them. Do not leave ashes banked about blow-off pipes as a protection.

Blowing Down

Except where the amount and frequency of blowing down is determined by chemical analysis, blow down freely at least once every twenty-four hours. Blow down the boilers at a period in the day when steam production is lowest.

Where a large amount of blowing down is necessary, open the cock or quick-opening valve first until it is half-open, and leave in that position until the water is lowered about half an inch in the water-glass. Then open wide all valves until the blowing down is completed. See that the cock or valve shuts tight and remains tight. Repair all leaky blow-off valves or cocks as soon as practicable. Use surface blow-off if installed until the undesirable conditions for which it is employed are corrected.

Where the water-glass is not in view of the operator blowing down a boiler, another operator should be stationed where he can see the water-glass and signal to the operator blowing down the boiler.

Blow-off Equipment

Maintain blow-off valves and cocks in good working condition, repair leaking blow-off valves as soon as practicable. See that they are in good working condition before putting a boiler in service and examine them periodically, when boiler is washed out and at times of internal inspection. Maintain in good condition the pipe and fittings between the blow-off valve and the boiler, together with their insulation, and inspect them periodically at time of internal inspection and particularly when the boiler is washed out. If the discharge end of the blow-off line is visible, watch it for the purpose of detecting leaky blow-off valves.

If any unusual or serious foaming occurs, check the fuel and air supply and close the steam outlet long enough to determine the true level of the water in the water-glass. If the level of the water in the glass is sufficiently high, alternately blow down some of the

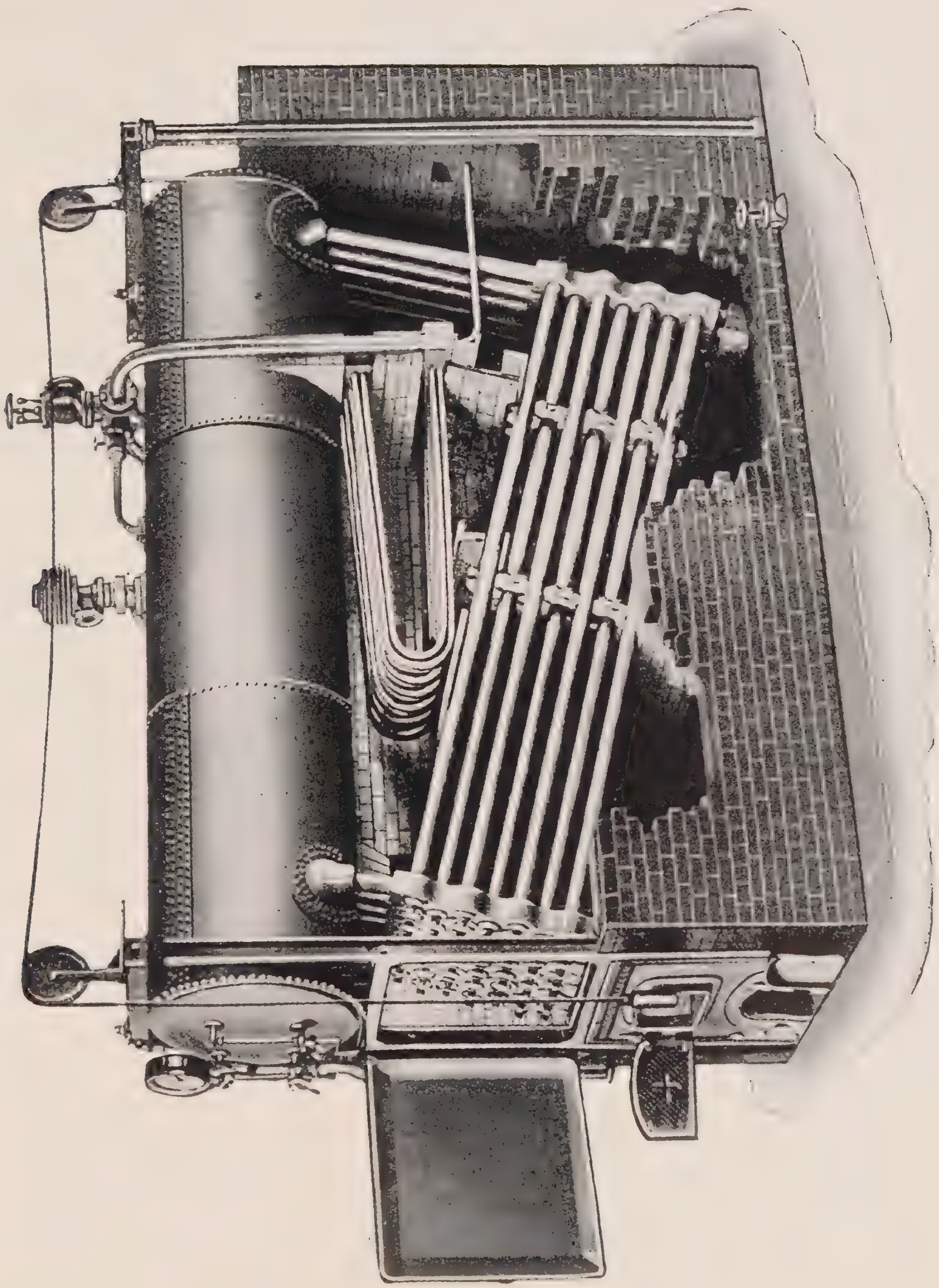


Fig. 2. Babcock and Wilcox Water Tube Boiler with Superheater.

water in the boiler and feed in fresh water several times. Use surface blow-off if installed. If the foaming does not then stop, bank the fire and continue the alternate blowing down and feeding.

To Empty Boiler

Allow the setting to cool slowly, particularly where there is much sediment in the boiler. After the setting has been cooled and there is no pressure on the boiler, open the vent and empty the boiler. When it is not practicable to empty a boiler at atmospheric pressure, blow it down at as low a pressure as is consistent with operating conditions. When the boiler to be emptied is set in a battery of two or more boilers, make sure that the blow-off valves that are opened are on the boiler that is to be emptied. As soon as the boiler is emptied, close the blow-off valves, remove the manhole plates, and when necessary, the covers of other openings.

Care When Examining Inside of Boiler

Before entering the drums or shell of a boiler, see that the blow-off valves, the main stop-valve, the feed-water valves, and other valves are closed. Use some reliable method of safeguarding any one entering the shell or drum.

Water Column

The gauge glasses in nearly all stationary boilers are connected to a water column in the manner shown in the diagram. The pipe leading from the top is connected to steam space of the boiler and the bottom pipe to the water space. A gate valve should be placed in each pipe leading to the boiler. Sometimes a whistle is mounted on the water column, operated by floats inside the column chamber. In case of high water the upper float is raised by means of a rod linking it with a valve which opens, causing the whistle to blow. Likewise if water gets low the lower float drops down opening the valve and the whistle will blow. Like many other automatic contraptions, the fireman is liable to put too much confidence in these tell-tale devices and become careless.

Water Gauge

It is necessary at all times to know the height of water in boiler under operation. This is indicated by means of a gauge glass. Usually this glass tube is a length of about 12 inches. It is held in place by special valve mounting, and made watertight by means of stuffing boxes as shown in Fig. 3. Sometimes it is connected direct to the boiler shell by pipe nipples, but more often to the water column. The glass should be so placed that its bottom end is about two inches above the tubes of a H. R. T. boiler.

When both valves are open, the level of water showing in the glass will be a true indication of the level of water in the boiler, but, if the top valve is closed, the pressure will cause the water in the glass to rise higher than the true level of the water in the boiler; while if the bottom valve is closed, the steam will condense at the top of the glass and fill the glass, thus indicating a higher level than really exists in the boiler.

Great care should be taken to make sure both pipes leading to the boiler are free from dirt and scale, for if either pipe becomes plugged, a higher water level than the true level

will be indicated. To test these pipes the bottom valve should be closed and the valve on the drain pipe from the bottom of the gauge opened. Steam should flow freely through. Next close the top valve and open the bottom one and again open the drain valve.

The pipes leading from the boiler to the water column should not be less than 1¼ inches in diameter; care should be taken that no air or water pockets are formed.

Test water glasses after replacing. Test all water glasses on a boiler when the boiler is placed in service, and when trouble is experienced with boiler compounds, foaming, priming, or other feed-water troubles that are apt to cause choking of the connections.

Water glasses and their connections should be kept free from leaks and no connections allowing a flow of water or steam from the piping between the water column or water glass and the boiler should be made, as such leaks or flow of water or steam will cause a false indication of the water level in the boiler.

The outlet end of the discharge pipes from water columns, water glasses, and gauge cocks should be kept open and in sight or hearing of operator while blowing down.

Keep water glasses well lighted and clean. When they need cleaning, replace them with clean glasses. Attempts to clean glasses in place, lead to possible cracking of the glass or choking from pieces of cloth or waste.

When a water glass has broken, remove the broken pieces and slowly open the valves to blow out any remaining pieces. Before inserting the new glass, see that the drain is open and that the glass is of the exact length required and that the connections are in line. Insert the glass with packing and set up the stuffing box nuts, taking care not to set them up too tight. Then warm the glass by opening the top valve slightly and let a small current of steam flow through the glass. Close the drain cock after the glass is sufficiently warmed, open the bottom valve slightly and when the level of the water in the glass has become stable, open the bottom valve wide and then open the top valve wide.

Unless the water glass is provided with a guard to protect the operator while replacing water glasses on boilers under pressure, or unless the operator wears a mask, the valves should be operated only by remote control.

Gauge Cocks

It is not well to put full confidence in the gauge glass as it is sometimes difficult to determine the water level, or again the reading may be wrong if the pipes leading to the boiler are not clean. For these reasons all boilers are equipped with two or three—usually three—gauge cocks as shown in Fig. 3. These cocks are fitted to side of the water column, if there is one, or to the boiler shell if there is not a water column. The bottom cock is generally placed about three inches above the tubes in H.R.T. boilers, the next about three inches above the first and the third about three inches above the second. The height of water in the boiler may be noted by means of these cocks. If only steam is issuing from the cocks a sharper sound is heard than if the steam is mixed with water. The attendant soon becomes accustomed to these sounds and can easily distinguish between them. The attendant can also distinguish the difference by sight. If only steam is blowing it issues in

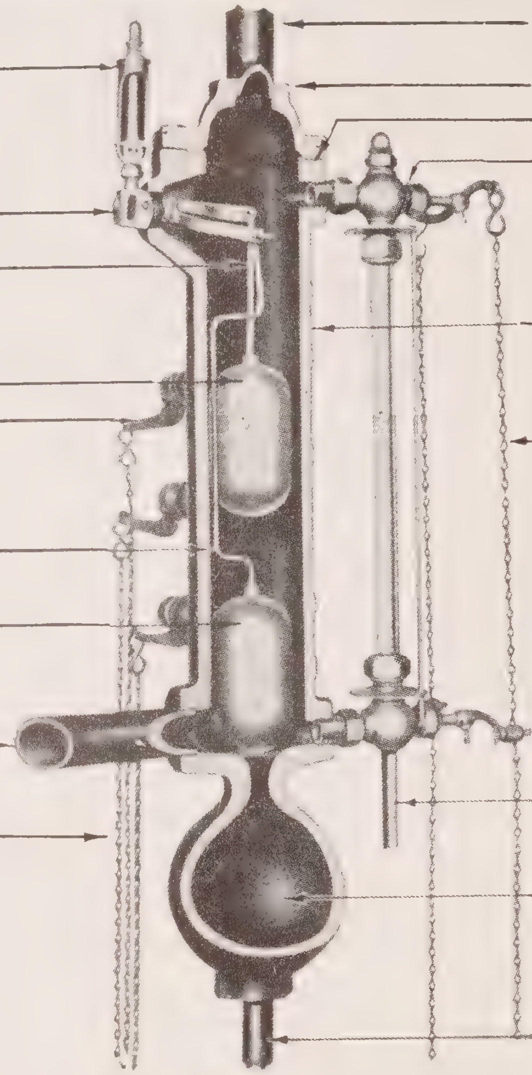


FIG. 3. Sectional view of Water Column showing automatic water alarm and gauge glass mountings.

a narrow straight line but if it be mixed with water it flares out in more of an umbrella shape.

If the gauge cocks are low enough the hand of the operator may be passed through the jet. If his hand becomes moist water is present but if it remains dry only steam is present.

Should the water be so low that it does not show in the glass but is still in the bottom gland it can be proven by opening the try-cock. Water will appear in the glass while the try-cock is open. This is due to the pressure being less in the glass than in the boiler.

Another and probably better method is to close the top (steam) valve of the water glass, and if there is water in the lower pipe it will denote its presence by rising in the glass.

Blow Off Pipes

All horizontal tube boilers should be set so that the back end is slightly lower than the

front; attached to the lowest point there should be a blow off pipe. This pipe should not be less than one inch, nor more than 2½ inches in diameter, and should be protected from the hot gases by a covering of magnesia, asbestos or fire brick.

The usual connection of the blow cff pipe to the boiler is a flange, riveted to the bottom of the boiler with a pipe threaded into the boiler.

Frequent inspection of the pipe should be made, as the protection is liable to be burnt away, exposing the pipe to the hot gases. Leaks at the joints are liable to occur, sometimes caused by the pipe being anchored solidly in the back wall where it passes through, thereby not allowing the free movement it should have to comply with the expansion and contraction of the boiler. The heat also is liable to cause the flange to eat away so that it is not capable of holding the pipe.

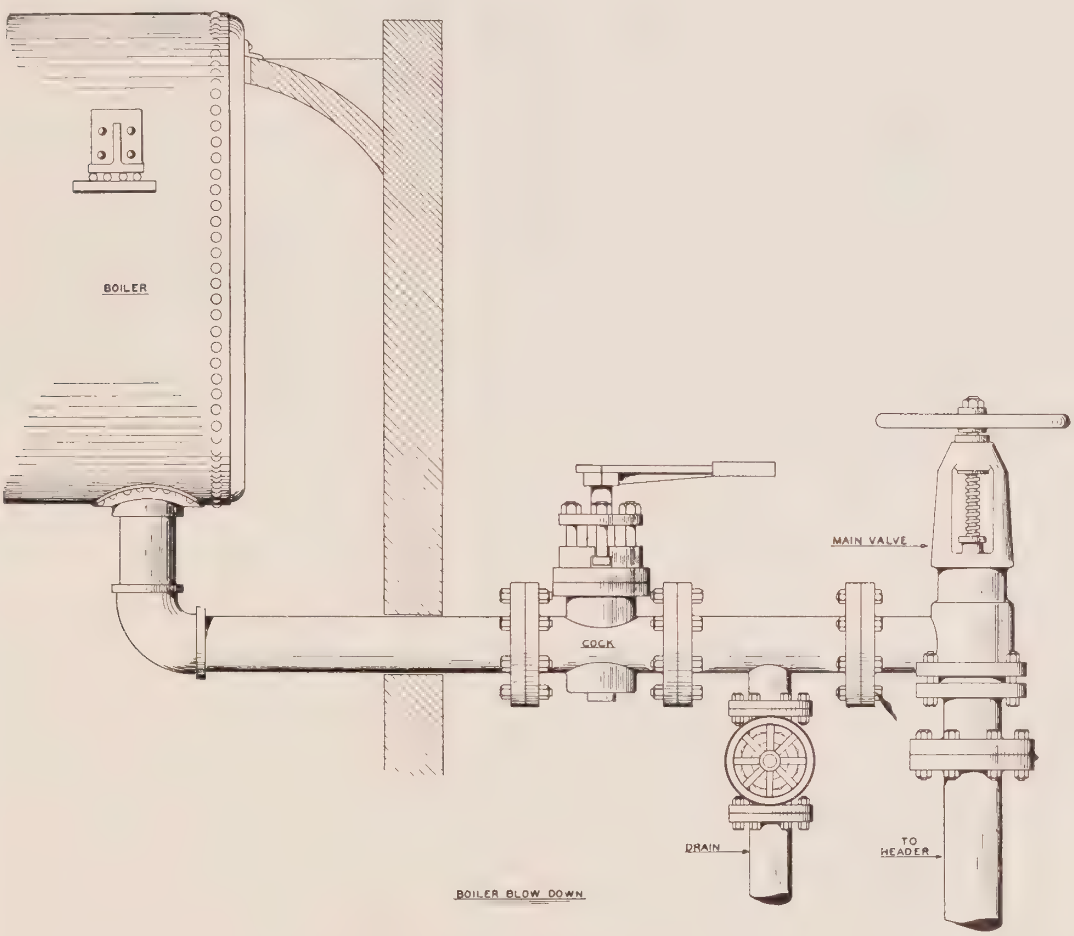


FIG. 4. Method of connecting blow piping and valves to boiler.

When the pipe is protected by a brick pier, care should be taken that the pier does not come in contact with the boiler, as it would interfere with the movement of the boiler due to expansion.

Blow Off Valves

Three types of blow off valves are commonly used. These are a specially designed valve, a gate valve, and a blow off cock. Globe valves should never be used for this purpose as it does not allow a straight blow through, and scale is liable to form under the seat, prohibiting the valve to close and thus causing it to leak.

There should always be two valves on the blow off pipe. It is good practice to have a gate valve and a plug cock or special blow off valve, in front. The gate valve should be opened first and closed last.

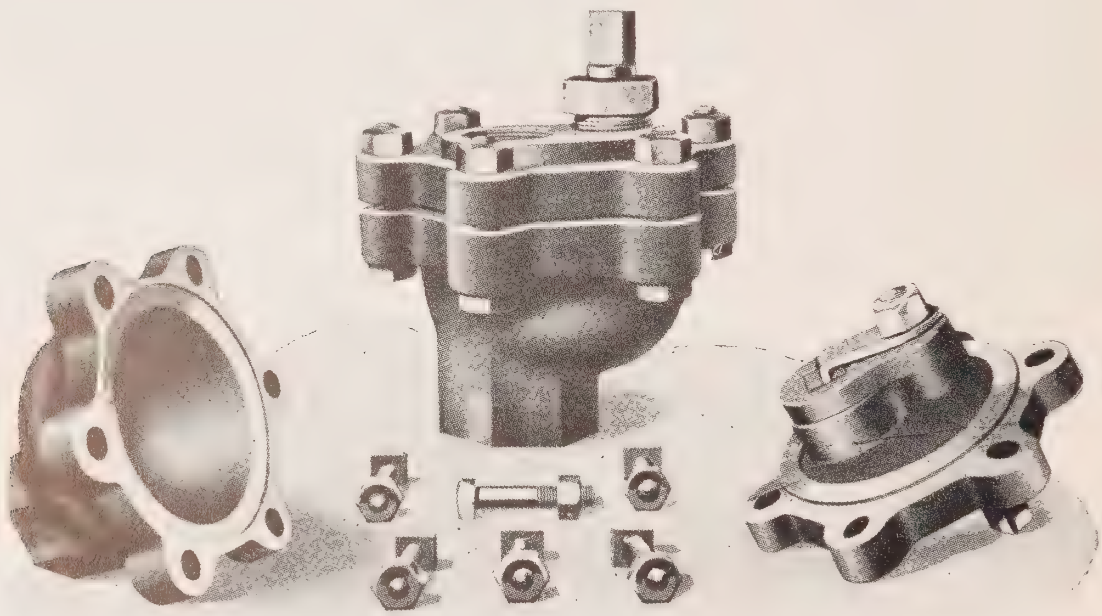


FIG. 5. Showing interior mechanism of blow off valve.

SAFETY-VALVES

According to Canadian Interprovincial Regulations each boiler shall be provided with a pop safety-valve or valves of approved design under the following conditions:—

(1) The springs and valves shall be cased in so that they cannot be easily tampered with.

(2) Provision is to be made to prevent the valves flying off in case of springs breaking.

(3) Each valve is to be provided with a cap for safety, protecting its adjustable parts, and fitted in such a manner that it can be efficiently sealed by the Inspector.

(4) Valve discs and seats shall be of non-ferrous material and valve seats must be secured in such a way that it is impossible for them to be raised with the valve.

(5) Each valve shall be provided with a substantial lifting device.

(6) The springs must have a sufficient number of coils to allow a compression under the working load of at least one-sixth the diameter of the valve.

(7) The springs shall not show a permanent set exceeding $\frac{1}{16}$ of an inch ten minutes after being released from a cold compression test closing the spring solid.

(8) Springs shall be so constructed that the valve can lift from its seat at least one-quarter the diameter of the seat before the coils are closed.

(9) With safety-valves over two inches in diameter, flanged connections must be used.

Spring-Loaded Pop Safety-Valves to be Used

Safety-valves shall be of the direct spring-loaded pop type, the valve disc and seat being either bevelled at an angle of 45 degrees to the centre line of the valve spindle or flat. The vertical lift of the valve disc measured immediately after the sudden lift due to the pop shall not exceed 0.15 inch. Safety-valves shall operate without chattering and shall be set and adjusted as follows:—

For boilers carrying not more than 100 pounds working pressure to close after blowing down not more than 4 pounds.

For boilers carrying a working pressure of over 100 pounds and not more than 200 pounds to close after blowing down not more than 6 pounds.

For boilers carrying over 200 pounds working pressure to close after blowing down not more than 8 pounds.

Minimum Diameter of Safety-Valve

The diameter of a safety-valve used on a boiler shall be not less than one inch.

This section does not apply to air or gas tanks nor to boilers under two horse-power capacity.

Connection of Safety-Valves to Boilers

Safety-valves shall be connected to the boiler independently of any other steam connection. They shall be attached as close to the boiler as possible without unnecessary intervening pipe or fittings. No valve of any description shall be placed between the safety-valve or valves and the boiler, nor on the escape-pipe between the safety-valve and the atmosphere. When an escape-pipe is used it shall be at least the full size of the valve, and shall have an open-ended drain to prevent water lodging in the upper part of the safety-valve or in the pipe. When an elbow is placed on a safety-valve escape-pipe, it shall be located close to the safety-valve outlet, and the pipe shall be securely anchored and supported. All safety-valve discharges shall be so located or piped as to be carried clear from the running boards or working platforms used in controlling the main stop-valves of the boiler or boilers. Each safety-valve shall be connected whenever possible in an upright position with its spindle vertical. (Sec. 268 I.P.R.)

We wish to particularly call attention to the sentence in the above paragraph which reads "No valve of any description shall be placed between the safety-valve or valves and the boiler, nor on the escape-pipe between the safety-valve and the atmosphere." The reason is so obviously plain that it should need no explanation. Should a globe-valve be on the

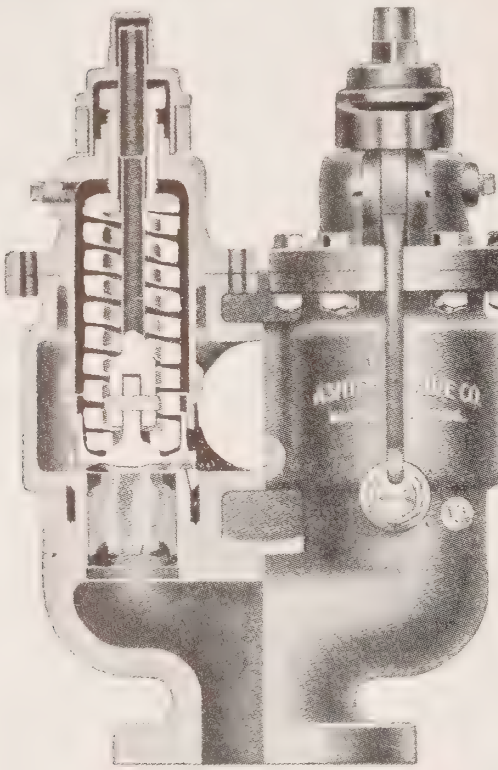


FIG. 6. Ashton twin safety valve.

line, and someone should close it, the safety-valve is put out of commission and no means left for the escape of excess steam.

Safety-valves shall not be connected to an internal pipe in the steam space, and the area of the opening to the boiler shall be at least equal to the aggregate area of all the safety-valves attached thereto.

Twin Valves

When the safety-valve area required is greater than the area of a 3½ inch diameter valve, two or more valves shall be used instead of one large valve; but when two or more safety-valves are required, valves up to 4½ inches in diameter may be used. Such valves may be either separate or twin valves made by mounting individual valves on "Y" bases, or duplex, triplex or multiplex valves, having two or more valves in the same body casting. When two or more safety-valves are used on one connection, the connection to the boiler shall have a cross-sectional area not less than the combined area of all the safety-valves with which it connects.

Every superheater shall be provided with one or more safety-valves near the outlet.

Pop Safety-Valves

The pop valve is provided with a skirt, see Fig. 7, which becomes filled with steam when the valve is open, so that the effective area of the valve is increased. As soon as the valve lifts, this increased area immediately takes effect; and the greater load on the spring

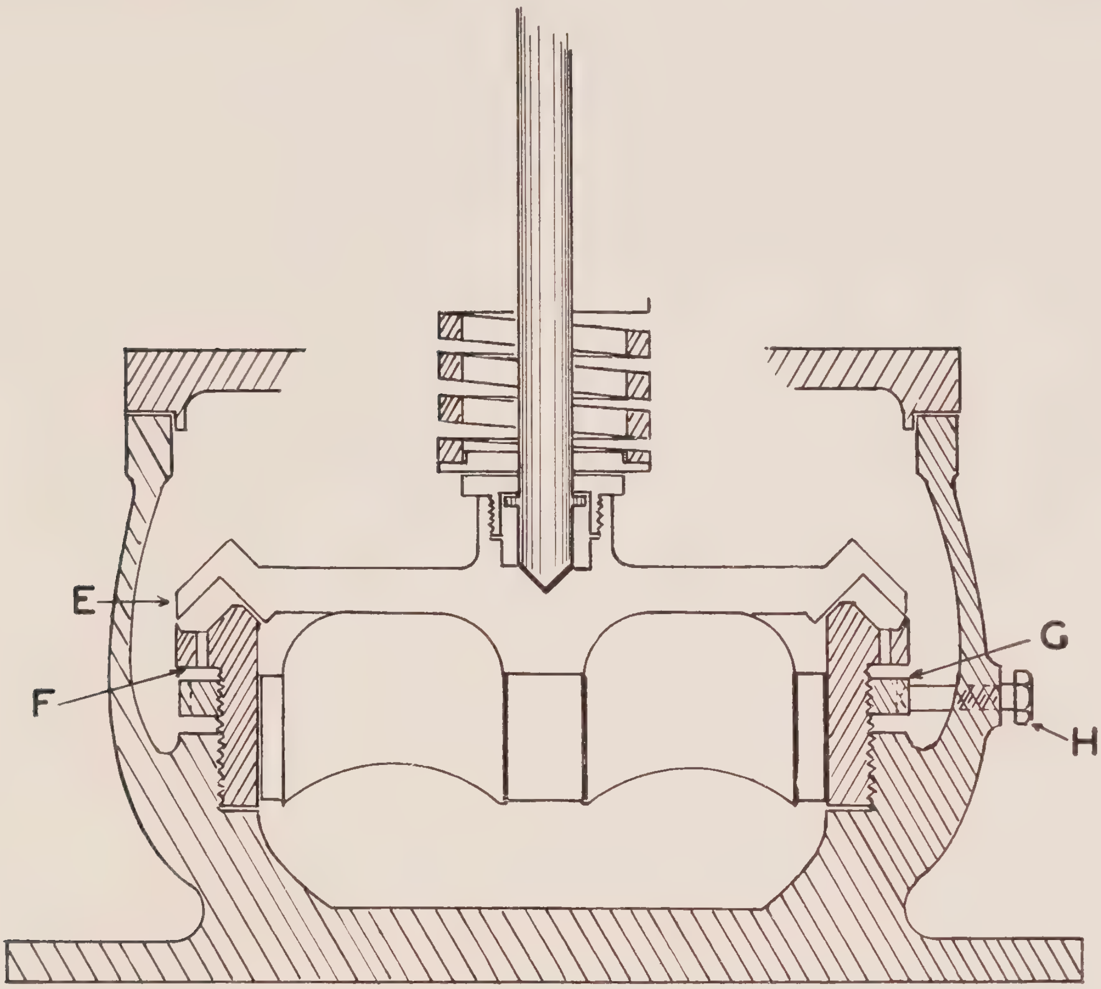


FIG. 7. Diagrammatical sketch showing how regulation of amount of safety valve blow down may be accomplished. "E" skirt of valve, "F" series of port holes to allow steam to escape from under the skirt. "G" adjustable angular ring which may be screwed up or down to vary amount of port opening "F". "H" set screw holding "G" when adjusted.

compresses it more than would be the case with a plain valve, and the valve opens wider. Once open, the valve will remain open while the pressure drops below that which opened it, because of the effect of the increased area. The pressure per square inch on the added area is less than the boiler pressure, and is dependent upon the freedom with which the steam can escape from under the skirt. Passages connect this part with an annular space called the "huddling chamber," and this chamber is provided with an adjustable outlet. If the huddling chamber outlet is closed, the pressure under the skirt will be greater, and the boiler pressure will drop very low before the spring can close the valve. If the huddling chamber outlet is wide open, the pressure in it and under the skirt will be small, and the valve will close with very little drop of boiler pressure. The difference of pressure between that necessary to open the valve and that at which the spring can close it, is called the "blowdown," and is adjusted by controlling the huddling chamber outlet.

It has been explained how the effect of the skirt is to cause the valve to open wide immediately upon opening at all. In closing, this action is reversed, for when the boiler pressure drops sufficiently to allow the spring to begin closing the valve, the pressure under the skirt drops and allows the spring to close the valve further, so that the action is cumulative and the valve closes quickly. Owing to the rapidity with which these valves open and close, they are called "pop" valves.

The valve may be opened to discharge at any pressure less than the relieving pressure by operating the hand lever.

General Instructions re Care of Safety Valves

Always apply valves close to the boiler or main supply of steam on short nipples or nozzles having full inside diameter. When otherwise connected they are likely to chatter when blowing, and will not give full capacity of relief, due to restricted steam supply.

Each safety-valve should be applied to a separate boiler nozzle, with no other engine or auxiliary pipe line connected thereto. This will insure the valves of having a full and steady supply of steam to maintain their full efficiency lift without fluctuation.

Joints between safety-valves and connections must be carefully made up. Red lead, or other similar material, used on screwed joints, should be put on sparingly and be applied only on the male connection. Packing used for gaskets on flanged joints should be carefully trimmed on its inside diameter. By following these instructions it will prevent any joint from working up into valves to clog them or make them leak.

Safety-valves should be placed in a vertical position. When otherwise applied they will wear unevenly and become out of alignment, which will cause them to leak by preventing true seating.

Valves should be operated frequently. If this does not happen in regular service at least once a day, they should be opened by hand, as can readily be done by use of the trip lever. This practice keeps the valves in good working condition and prevents the accumulation of dirt or other foreign matter that might clog the important working parts.

Never change set pressure adjustment of valves when they do not operate at apparently the correct pressure, unless the steam gauge is known to be absolutely correct. Gauges are more likely to be inaccurate than safety-valves owing to their more sensitive action and delicate construction.

The cause of safety-valves leaking may be due to several reasons. Generally it is because of some foreign substance having blown out of the boiler or the safety-valve connection and becoming lodged on the valve seat. When this occurs, the valve should be taken apart at the first opportunity, and the seat cleaned. If the seat has become scratched or slightly defaced, it can be made perfect by grinding it with fine quartz and oil. If more than slightly defaced it will require machining, in which case the same amount of metal should be removed from the lip as from the seat.

As previously stated, valves will also leak if red lead or packing from the connection

joints gets into the valves. They will also leak if they are allowed to chatter, due to improper installation or wrong adjustment of the pop, giving too small a blow-down.

Valves having long, unsupported outlet pipes connected to them, are often found to be leaking, because of the weight of the pipe unduly straining the valve body and distorting the seat. Such pipes must be supported otherwise than by the valve only.

Lifting mechanism attached to safety valve levers must be so arranged that, when it is not being used, the lever will stand in its normal position. If there is the slightest drag on the lever the valve is likely to leak.

The Cause of Safety Valves Chattering

This fault in operation is usually due to wrong application such as mentioned in above paragraphs. Pop safety valves give such a large and sudden relief that they must be so connected that they will obtain a full supply of steam to keep them well off their seats during their entire operation. They are also so sensitive that if an engine pipe or other auxiliary is connected to the safety valve nozzle, it will cause sufficient fluctuation of pressure to make the valve correspondingly fluctuate in its lift when blowing and result in chattering.

Valves which have the pop, or blow-down, regulated too fine will chatter. The adjustment should be such that the difference between the opening and closing pressure will not be much less than three pounds, otherwise the valves will remain on a balance.

Valves which have an excessive blow-down, or pop, such as over 5 pounds, are usually hung up in the head of the wing valve, or between the valve wings and the seat bushing. They should be taken apart and cleaned. If the spring is too light the pop is likely to be too heavy. A satisfactory pop for ordinary pressures is 3 pounds, and for high pressures 5 pounds. Adjustments should be made within these limits for satisfactory service and economy in steam. The outside pop regulator will accomplish this under normal conditions.

Safety valve springs have a limited range of service. They cannot be used for a greater range than 15 pounds above or below the original set pressure without impairing the efficiency of the valve and the regulation of the pop control. When a greater change of set pressure is desired, new springs of proper strength must be used.

Screwing down safety valve springs beyond their maximum range, to make hydrostatic test, subjects them to an excessive strain that may destroy their life and efficiency. It is a bad as well as a dangerous practice.

Care should be exercised to prevent the accumulation of scale, dirt or other foreign matter from collecting between the coils of the spring of the safety valve. Where boilers are connected into a common steam header and operate under the same working pressure and some of the boilers have allowable working pressures greater than others, never set a safety valve to pop at a pressure greater than that allowed on the weakest boiler, unless the lower-pressure boilers are equipped with non-return check valves and sufficient safety-valve capacity is added to the lower-pressure boilers or to the low-pressure header to take care of the capacity of the higher-pressure boilers.

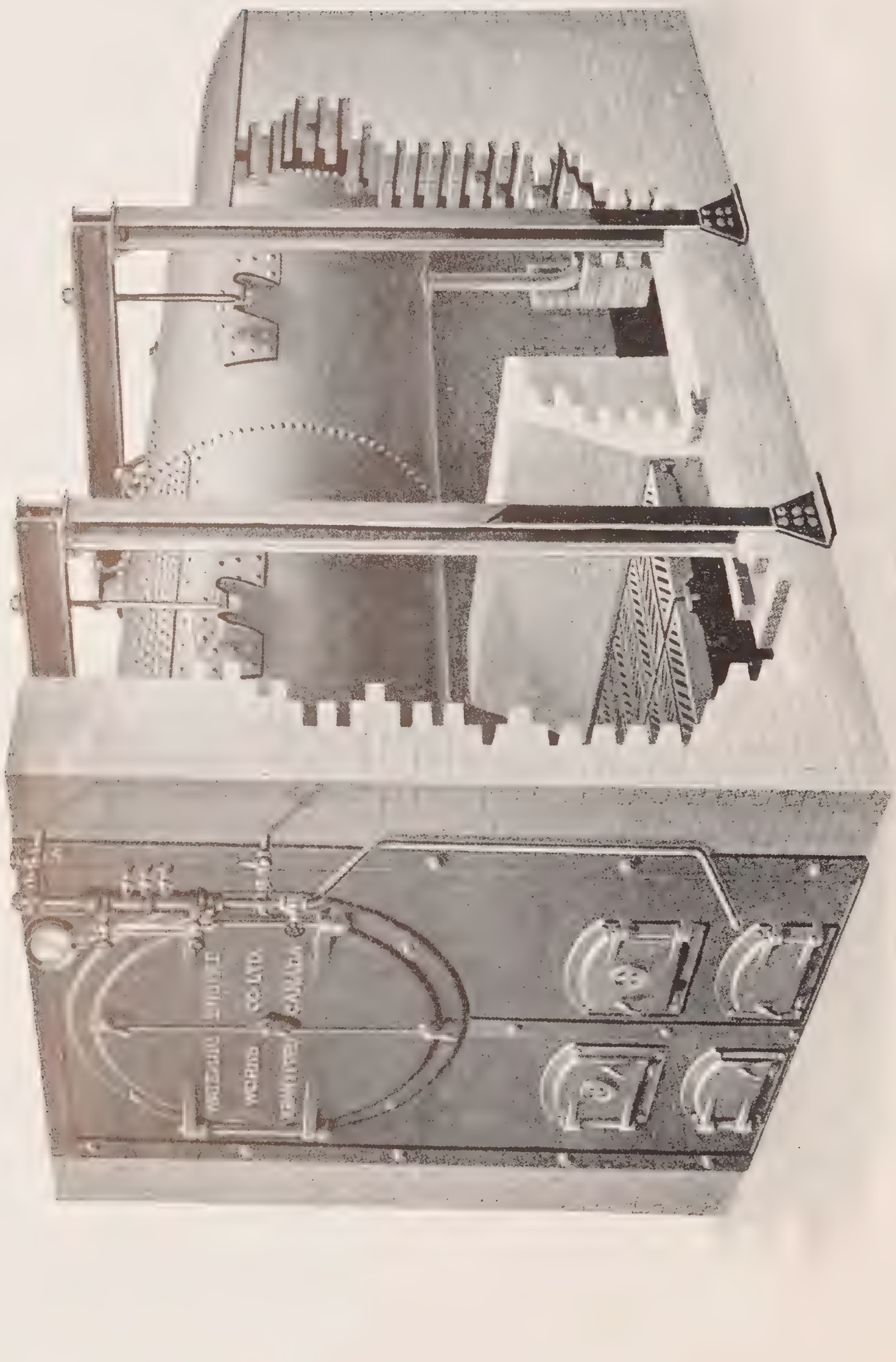


Fig. 8. Showing method of supporting boiler drums.

Priming of Boilers

A boiler is said to prime when water of the boiler is carried up and over with the steam as it is discharged from the boiler. Priming occurs when the water surface is so close to the steam outlet that particles of water are projected upward in the steam space by ebullition of the water, or bubbles in the steam as it flows from the boiler. Remedies for priming due to ebullition are to have a larger disengaging surface of the water and deeper steam space in which the point of discharge is higher above the boiler water line. The activity of ebullition can be retarded temporarily by checking the fires or feeding more rapidly, but for a boiler already constructed, the permanent remedy is to carry lower water level, or provide a dry pipe or other form of separator within the boiler, or take the steam from the top of a steam drum or separator placed above the old outlet.

Foaming of Boilers

Foaming is caused by any materials, either dissolved in the water or suspended in it, which retard or interfere with the free escape of steam from the water to the steam space. A collection of scum on the water surface is also a common cause of foaming. Such a scum may be caused by presence of oil, vegetable matter or sewage. If the water contains alkali, any animal or vegetable oil that may find its way into the boiler is changed into soap, which forms suds and causes foaming. Similar foaming may also be caused by concentration of certain salts in the water, as from use of soda ash or other boiler compounds. Foaming that is productive of priming may be reduced, and in most cases can be prevented, by blowing down regularly and sufficiently; by cleaning the boilers regularly; by using feed water containing little or no oil, alkalies or vegetable matter; and by not forcing a boiler too much beyond its rated capacity.

To Overcome Foaming and Priming

If any unusual or serious foaming occurs, close the steam outlet valve long enough to determine the true level of the water glass. If the level of the water in the glass is sufficiently high, blow down some of the water in the boiler and feed in fresh water. Use surface blow off if installed. Repeat the alternate blowing down and feeding several times, and if the foaming does not stop, bank the fire and continue the alternate blowing down and feeding. Test safety valve or valves and connections and connections of pressure gauge, water column and water glass for any sticking or choking. Determine positively the cause of foaming and adopt measures to prevent its recurrence.

Effect of Oil in Boilers

Every precaution should be taken to avoid common oils from entering a boiler. Not only will oil cause the boiler to foam badly, but it has a tendency to mix with other impurities of the water which when the boiler is not in use will settle on the metal in a spongy mass. This grease prevents the water from coming in contact with the metal, with the result that the metal becomes overheated and destroyed, sometimes causing an explosion.

Kerosene oil is sometimes used with good results to prevent scale forming or to loosen scale already formed. It has, however, a very strong tendency to cause the boiler to foam and should be used very carefully and in small quantities, if at all.

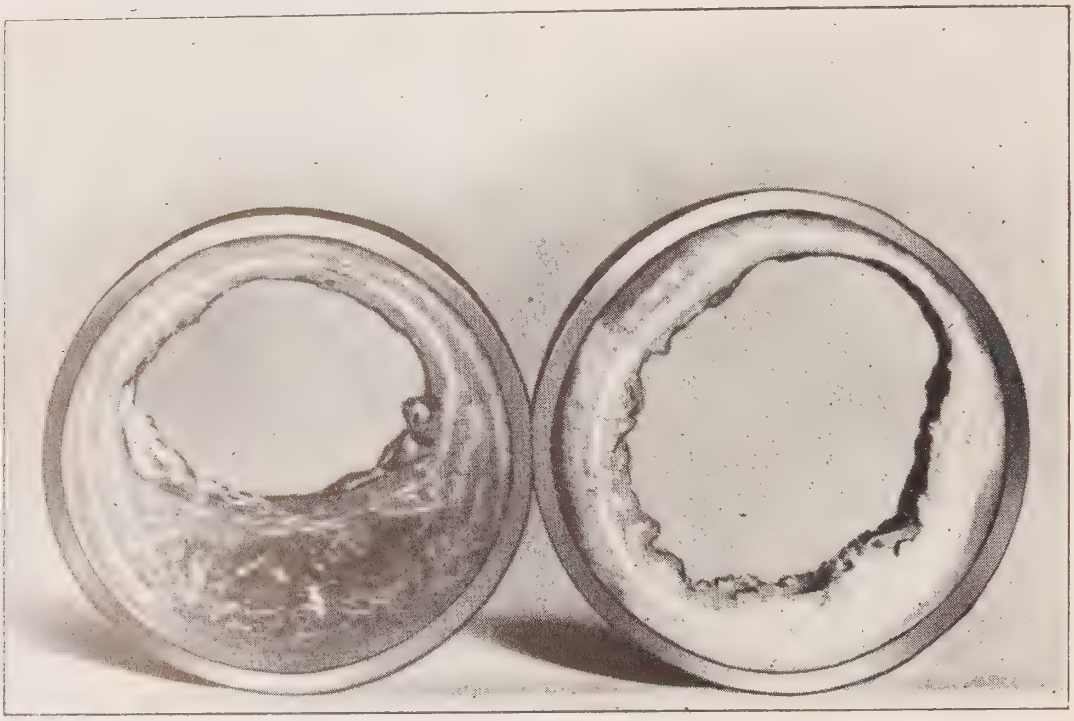


Fig. 9. Actual photograph showing scale collection in sections of tubes taken from a boiler which operated in Ontario.

Effect of Scale in Boiler

Almost all substances are to a more or less extent soluble in water. The boiler feed water is therefore liable to contain solid forming material of almost any kind. The most common and most troublesome substances are calcium carbonates and magnesium carbonates, which tend to form a soft scale, and calcium sulphates and magnesium sulphates, which form a hard scale which is difficult to remove.

The effect on the efficiency of the boiler and the liability to injury to the shell and tubes cannot be determined by the thickness of scale that has collected. A soft spongy scale may not have any material effect, even of considerable thickness, as the heat is capable of travelling through the scale as rapidly as it does through the metal. On the other hand, a compact solid scale may have a very material effect, even though it be deposited in a very thin layer.

Scale of a thickness of an inch or less will cause a loss varying from almost nothing to as much as 10 or 12 per cent, depending upon the nature of the scale formation.

Scale having heat insulating properties does not conduct the heat to the water rapidly enough, with the result that the metal of the tube becomes overheated, causing expansion and contraction, which shortens the life of the tube and is liable to cause bulging and a possible rupture of the shell.

Removing Scale from Boilers

When feed water contains a large amount of scale forming substances it should be

purified before it enters the boiler. The methods by which this may be accomplished, however, comprise too large a subject to discuss at this point but will be taken up under the heading of water softening.

Scale forming substances composed of carbonate compounds can to a large extent be removed from the water by first heating the water in a feed water heater before it is pumped to the boiler. Sulphate compounds, however, cannot be removed so easily. Substances known as boiler compounds are commonly inserted into the boiler while it is working. These compounds have the effect of loosening the scale from the metal and at least a portion is removed when the blow off valve is opened.

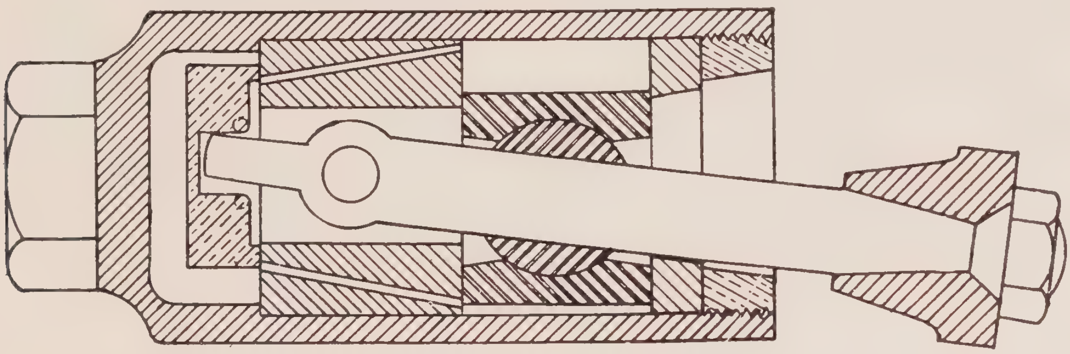


FIG. 10. Hammer type tube cleaner.

Boiler compounds are composed almost entirely of soda-ash. As different scale-forming substances are found in different localities it is always well to have the water used in any plant analysed and a suitable compound recommended to be used to counteract the scale-forming substances of the particular locality.

Hard scale is difficult to remove by mechanical means. The work can often be very materially lessened by inserting into the boiler a quantity of caustic-soda and allowing the boiler to steam for several hours before closing down to be washed out. The soda will have a tendency to soften the scale and make it easier to remove.

Scale Removing by Mechanical Means

When the water has been entirely emptied out of the boiler, the manhole and handhole covers may be removed. Care should be taken when opening the holes, that the boiler does not still contain pressure or that a vacuum has not been created. The top gauge cock should be opened to provide an escape for pressure or an entrance for air in case of vacuum.

Scale varies from a soft deposit, which is easily removed, to a very hard material which is difficult to cut with a chisel. When the softer material is encountered it is easily washed out with a stream from a hose. Hard scales are removed with scaling tools operated by hand or power. There are two general types of mechanical tube cleaners on the market, viz., hammers and cutters.

The hammers are operated by steam or air. The hammer is inserted in the tube and strikes a hard blow first on one side and then on the other. The scale is removed by the vibrations of the tube.

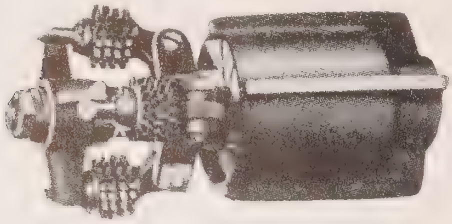


FIG. 11. Water Turbine type tube cleaner.

Great care should be exercised in the handling of the cleaner that the tubes be not deformed.

Figure 11 represents a type of cutter used in removing scale, known as the turbine tube cleaner. It is operated by a small water turbine inside the casing. These may be purchased in any size to fit the various sizes of tubes. Water is led into the cleaner through a flexible hose and the cutters are caused to revolve rapidly. By passing the cleaner back and forth through the tube the scale is cut and the water being discharged from the cleaner carries the loose scale with it.

EXTERNAL CORROSION

Leaks

Boilers in service may be exposed to external leaks of different kinds which tend to corrode the shell. The operator should guard against leaky safety valves and steam mains, which drop condensation on the boiler and cause external corrosion, especially where the water runs under protective coverings.

Leaky manholes and handholes, particularly where ash and soot can collect, are especially dangerous as they corrode the shell rapidly. Such places should be kept clean and tight.

The boiler operator should periodically examine the blowoff pipe nipple when it is screwed into the mud drum or shell. Corrosion is liable to weaken the nipple at this point.

Leaky tubes should be rolled or replaced promptly, to avoid possible corrosion of the tube sheet.

Replacing Destroyed Tubes

To remove the old tube care should be taken that the tube sheet is not in any way injured. The tube may be loosened by using a cold chisel and crushing the ends in until they are loose in the holes, after which the tube may be drawn out.

The new tube should be measured to make sure it is of the proper length. If the tubes are to be beaded they should extend past the tube sheet an amount sufficient for beading. Provided the holes in the tube sheets are in good condition the new tube may be inserted and placed in its proper position, allowing the same amount of projection at each end.

When the tube has been placed, a tube expander is inserted in the end and the portion of the tube which comes in contact with the tube sheet is rolled, thereby expanding it until the metals of the tube and the tube sheets are solidly in contact with one another. This makes a steam tight joint.

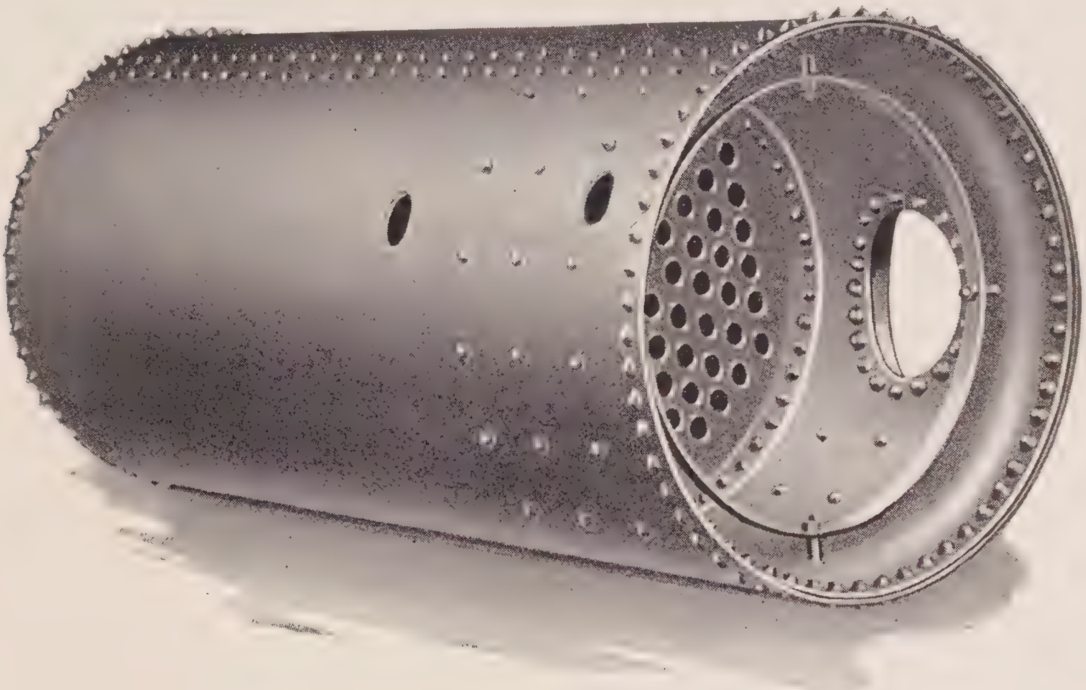


FIG. 12. A type of vertical boiler used on construction work. Note the method of forming the water leg.

Sometimes the holes in the tube sheet where tubes have been replaced several times become enlarged so that the tube cannot be expanded sufficiently to fill the hole. In this case a copper ferrule is first inserted in the hole and the tube placed in the ferrule, when the whole is expanded until steam tight.

The following is a copy of the Interprovincial Regulations regarding tubes:—

Tubes must fit the holes in the tube sheets as neatly as possible before expanding, the end nearest fire being a driving fit when applied. The ends must be prepared for this and the holes in sheet where tube is entered to be only large enough to allow free entry of tube. The ends of tubes in fire tube boilers must not extend more than three-sixteenths to one-quarter inch beyond the sheet according to the thickness of tube, and then be beaded against the tube sheet without cracking. The use of copper ferrules is permitted. A fire-tube boiler shall have the ends of the tubes substantially rolled and beaded or rolled and welded at the firebox or combustion chamber end. In water-tube boilers and super-heaters, the ends of all tubes, suspension tubes and nipples shall be flared not less than one-eighth inch, over the diameter of the tube hole, or they may be flared not less than one-eighth inch, rolled and beaded, or flared, rolled and welded. The ends of all tubes, suspension tubes

and nipples of water tube boilers and superheaters shall project through the tube sheets or headers not less than one-quarter inch nor more than one-half inch before flaring. Machine welding of tubes when retipping is strongly recommended. Acetylene or hand welding will be prohibited, unless by special permission in writing from the Chief Inspector, in which case no more than 50 per cent of the tubes in high pressure boilers will be allowed to be welded in this manner. (Sec. 258.)

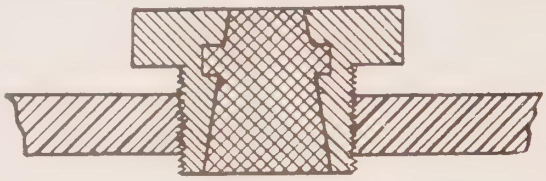


FIG. 13. Fusible Plug.

Fusible Plugs

All boilers used in Ontario must be equipped with fusible plugs, their purpose being to act as a precaution against the boiler being burnt owing to low water.

While the water is in contact with the plug, it carries away the heat and does not allow the banca tin to fuse, but when the water drops lower than the plug, the banca tin melts and allows steam to escape, thereby giving warning of low water.

Care of Fusible Plugs

If fusible plugs are used, see that they are kept in good condition and that they are not used for more than one year as provided for by the regulations. When the boiler is open, scrape clean and bright the exposed surfaces of the fusible metal as well as the surface of the boiler near the plugs. If the fusible metal does not appear sound, renew the plug. Never refill a plug with anything but new metal of a quality specified in the regulations.

Steam Gauges

According to Interprovincial Regulations every boiler shall be provided with a correct steam pressure gauge of approved design which shall be tested by the inspector at the time of the inspection, and which must be set to correspond with a standard test gauge and placed so as to be plainly visible by the operator. Traction and portable boilers shall be provided with a steam gauge of double tube type.

All steam gauges shall be connected directly to the boiler and shall be fitted with a trap or equivalent device sufficiently large to fill the gauge tube with water; a cut-out cock with a level handle must be placed between the trap and the boiler to which it is to be directly connected.

A one-quarter pipe size connection must be provided on every boiler to permit inspector's gauge to be connected above the cock on trap pipe for the purpose of testing in service the working steam gauge.

Steam gauges are graduated to read pounds pressure per square inch above atmospheric pressure.

The dial gauge was invented by Mr. Bourdon and is now known as the Bourdon pressure gauge. Its principal feature is a flattened tube bent into the form of a curve (see Fig. 14), one end being closed and the other end open to the pressure to be measured. It depends for its working on the principle that a flattened curve tube tends to straighten out when subject to internal pressure, since there is more area exposed to pressure on the outside of the curve than there is on the inside.

One end of the tube is made fast while the other end is free to move. To the free end is attached levers and a rack and pinion, which moves the hand.

Vacuum gauges are built on exactly the same principle, but are calibrated to read pressure less than atmospheric pressure. They are usually calibrated to read in inches of mercury instead of pounds.

This gauge should be tested by comparing with the readings on a Mercury Column.

Sometimes gauges are built to read both pressures below atmospheric pressure and pressures above atmospheric pressure. These are known as compound gauges.

When in operation compare boiler steam gauges frequently. Test at times of external inspection, when the boiler is placed in service after periods of shutdown for internal inspection or repairs and after an extended period of shutdown. When the safety valve pops, note the reading of the gauge and, if the reading is not in agreement with the stipulated popping pressure nor with gauges on adjacent boilers operating under the same pressure, test the gauge. See that the gauges are tested when trouble is experienced with boiler compounds, foaming, priming, and other feed-water troubles that are apt to cause choking of the gauge connections.

Keep the gauges well lighted at all times and the dials and glass covers clean. See that the glass cover is maintained tight and whenever the glass is broken that it is replaced as soon as possible.

When a boiler steam gauge not in use is likely to be subjected to freezing temperatures, drain the connections and gauge.

For Care and Maintenance of Pressure and Vacuum Gauges

All gauges used on steam must be protected by a water trap of sufficient capacity to fill the gauge tube, and thus prevent any steam from entering the tube, the heat from which would otherwise anneal it and render it useless. Joints between the trap and gauge must be absolutely tight to prevent leaking of water from the trap. Gauges should be protected from external heat exposure as far as possible. A gauge that is unduly heated will register inaccurately, due to expansion of the various parts of its operating mechanism. Boiler gauges should be piped direct to the steam drum, or main steam chamber, with no intervening fittings, except the trap and stopcock.

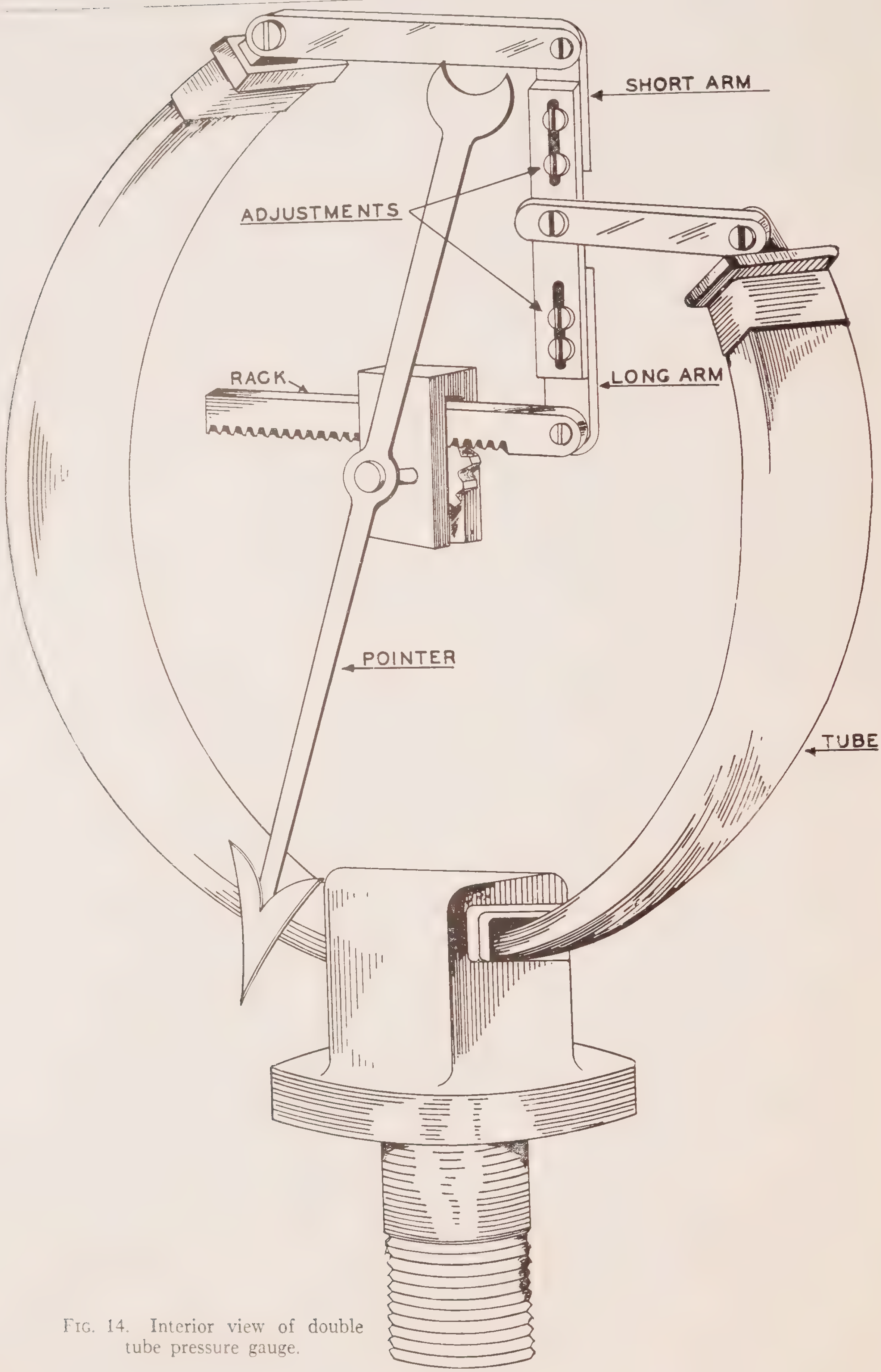


FIG. 14. Interior view of double tube pressure gauge.

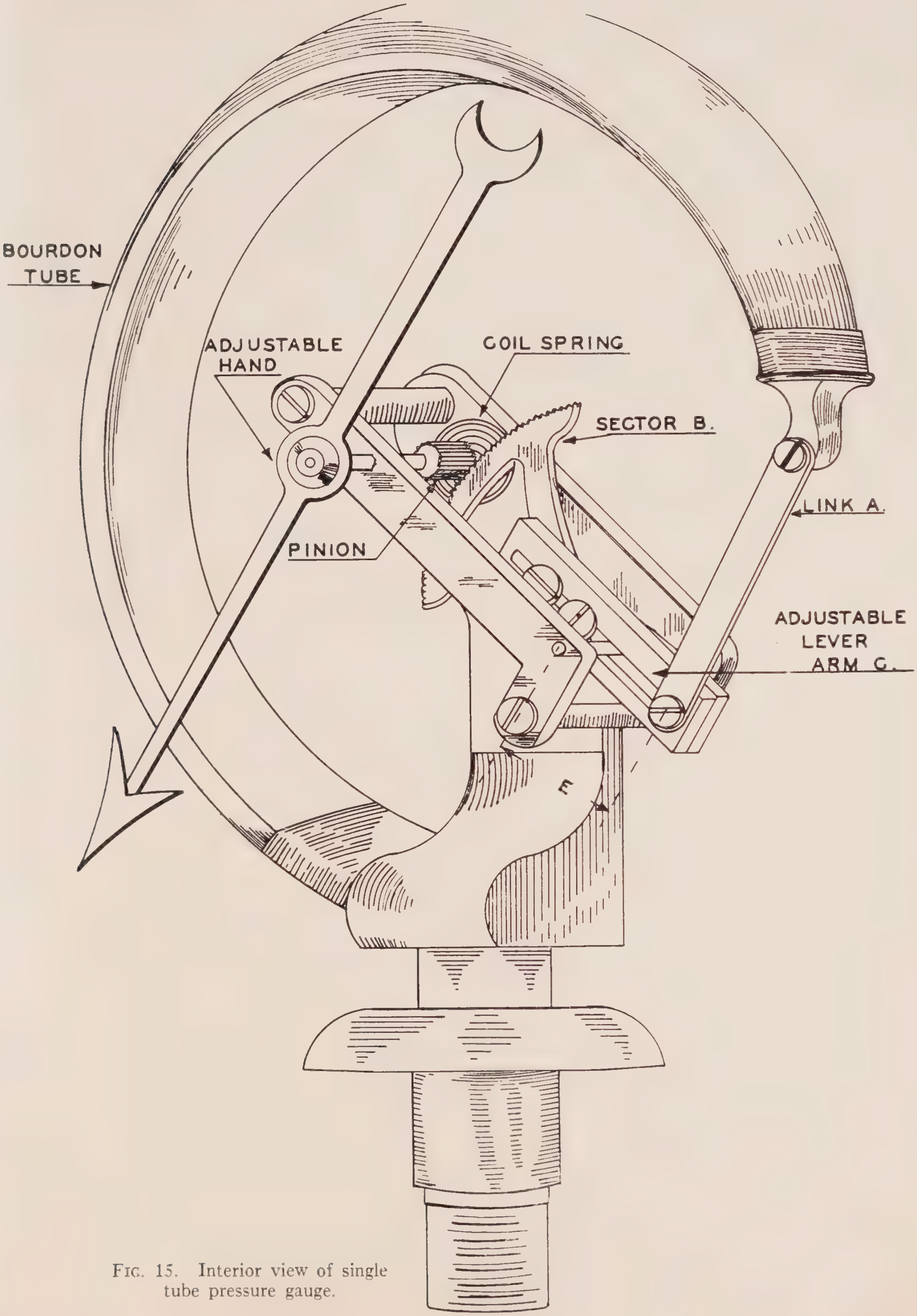


Fig. 15. Interior view of single tube pressure gauge.

Gauges that are correct will frequently be found to register a few pounds heavy, due to the weight of the column of water, or other liquid, accumulated in the gauge pipe. To correct this on such an installation the gauge hand requires resetting to compensate for the added pressure caused by the weight of the liquid.

Care should be used in attaching gauges to pipe, or other connections so as to prevent any strain on the gauge by being screwed on too tight. When attached to brackets, or other holdings, by means of screws through the back flange of the gauge case, the bearing must be sufficiently smooth and flat so that the gauge case will not be distorted when properly fastened to it, otherwise the gauge will not register accurately.

Gauges are usually made with from two to five pounds takeup, which holds the hand firmly against the stop pin, and thus prevents them from being jarred loose from their spindles in shipment, or when otherwise handled. For this reason there is an unequalled spacing in dial graduation between the stop pin and the first pressure marking. When gauge hands require resetting to correct inaccuracy they should be removed by a gauge hand puller, and afterwards refitted to the spindle by a very light hammer blow that will not bend the spindle.

Gauge tubes which develop defects in service, such as cracks or pinhole leaks, cannot be satisfactorily repaired by soldering, but should be replaced.

A steam gauge is considered tested when it has been compared and made to agree with a dead-weight testing device, or a test gauge which has been so tested. When compensation for waterleg has been made, make an equivalent allowance in the reading of the test gauge or dead-weight testing device. Use only a reliable gauge for a test gauge and use it exclusively for testing gauges in service.

Feed Arrangements

Each boiler shall have a feed pipe fitted with a check valve and also a stop valve between the check valve and the boiler. When globe valves are used on feed piping the inlet shall be under the disc of the valve. The feed water should be fed at the coolest part through an internal pipe where possible, but never near the parts of a boiler that are exposed to the direct heat of the fire or through the blow-off connection. The feed pipe of a boiler shall have an open end or ends inside the boiler and when an internal pipe is used it shall be connected to a properly designed brass or steel bushing or flanged connection at the inlet to the boiler. The internal and external pipes shall form a continuous passage but with clearance between their ends, so that the removal of either will not disturb the other.

Control of Water-Level

Periodical inspections should be made for possible scale and defective check-valves in the feed-line. For locating deposits or other obstructions in a feed-pipe, it is good practice to have a pressure gauge placed on the discharge chamber of the boiler feed-pumps, or on the discharge pipe outside of the feed-pump. When it becomes necessary to maintain an unreasonably high feed-water pressure, examine the feed-water lines for choking due to scale or other causes.

Special and constant care should be exercised to maintain a proper water-level in the boiler, and to provide a continuous rather than an intermittent supply of water to the boiler. Never depend entirely upon automatic alarms or feed-water regulators, no matter how effective or valuable these devices may be.

The first duty on entering a boiler-room is to ascertain whether the communications and valves between the boiler and the water glasses are free and open, especially when starting up in the morning, whether the fires have been banked up overnight or not, by blowing down the water-columns and water-glasses and noting the promptness of the return of the water to the glasses. Try the gauge cocks also until sure of the water-level. This should be done at the beginning of each shift and preferably before the relieved shift has gone off duty. It should be done after replacing water-glass and more frequently when trouble is experienced with boiler compounds, foaming, priming and other feed-water troubles that are apt to cause choking of the connections.

Have the water-column well lighted and keep the glass clean. Do not allow steam to leak from the water-column or its connections, as this will cause the water-glass to show a false water-level. Keep the outlet end of the discharge pipes from the water-column, water-glasses and gauge-cocks open and free from obstructions.

When the level of the water is not visible in the water-glass, try the gauge-cocks to determine whether the level of the water is above or below the water-glass. If the water-level is below the water-glass, stop the supply of air and fuel and close the dampers and ashpit doors, unless you are in touch with the entire situation as to boiler feed-water supply and positively certain that it is safer to continue steaming the boiler than to reduce the steaming rate. If found advisable not to stop the steaming rate of the boiler determine the cause, and remedy it immediately. If found advisable to stop the supply of fuel and air, do not change the feed-water supply, open the safety-valve or change the steam outlet-valves, or make any change that will cause a sudden change in the stresses acting on the boiler. In the case of hand-fired boilers, do not disturb the fire except to cover it with green coal or wet ashes; where stokers are used, stop the fuel feed and open the firedoors. After the fire is banked or out, close the feed-water valves. When the boiler is sufficiently cooled, close the firedoors and cut the boiler off the line. Determine the cause and remedy it before the boiler is again placed in service. Also examine the boiler for overheating.

Watch carefully for any sign of oil in the feed-water heaters, water-glasses and blow-downs. If a boiler becomes coated with oil or grease, shut down the boiler as soon as practicable and clean it thoroughly. If the amount of oil or grease is considerable, boil out the boiler.

Boilers Out of Service

Where boiler has been taken off the line for an idle period, it should be made certain that all feed and steam valves are shut and do not leak.

When a boiler is out of service for a long time, the outside exposed portions should be given a coat of red lead, black japan, tar paint or boiled linseed oil, to prevent corrosion.

The damper should be closed. All accumulations of ash and soot should be carefully and completely removed.

If the water is not removed when laying up the boiler, it should be completely filled and the water heated to drive off any air contained in the water. Sometimes a quantity of soda ash is added. After the boiler is completely filled with water, close all openings making sure the boiler is air tight. If the boiler when being laid up, is emptied of water, different methods are advocated. Some engineers prefer to pour several gallons of crude oil in the top of boiler before removing the water. As the water is allowed to drain out of the blow-off, the oil will form a film over all the plate, protecting it from the air and preventing rust.

Before the boiler is again put in use, care must be taken that all the oil is removed by adding soda ash and boiling it out.

Another method used, is to simply empty the boiler, making sure that all water is mopped up and the boiler is perfectly dry. Leave the manhole and handhole plates off to allow circulation of air. Be sure no water or steam is leaking into the boiler. Some engineers advocate the placing of pans of lime inside the boiler to collect any moisture. Care should be taken that the lime does not come in contact with the metal and is contained in earthen vessels.

Boiler Inspection

Many engineers appear to think that boiler inspection is the duty of Provincial Government Inspectors or Boiler Insurance Company's Inspectors, and that the annual visit of the Inspector is all the inspection required.

Discussion is continually taking place as to whether the boiler inspectors should graduate from the boiler operator's class or the boiler maker's class. There are good arguments on both sides, but we do not wish to discuss the matter here. What we wish to impress upon every operating engineer is that he should be a boiler inspector so far as it concerns the boiler he is operating. He should not be satisfied with an annual or semi-annual inspection, but should inspect his boiler both externally and internally upon every available opportunity. Below we give a few suggestions as to the manner of procedure, although they do not cover all the points necessary for a full examination.

Preparing for Inspection

If possible the engineer should have a blue print of the drawing of the boiler and setting so that he may be able to check up as the inspection proceeds, and also should have a pencil and note-book handy to make notes for future reference. He should carry a mason's or small chipping hammer, which can be used to knock off any scale or clinker, and to tap rivets, braces, tubes and plates where defects are likely to be found. Of course he must have a light in the form of a well guarded electric light, candle or flash-light.

In preparing a boiler for inspection it should be blown down a few inches in the regular way while steaming. Draw the fire and leave the ash-pit door and dampers open in order

that the cool air can circulate through the boiler to all parts. Do not open the smoke-box front, and thereby stop the circulation of air through the boiler and retard the cooling of same in the natural way. When the pressure has dropped to zero and the brickwork has sufficiently cooled, open the blow-off and allow the boiler to drain dry. Make sure to have a vent open at the top of the boiler, otherwise a vacuum will be created in the boiler. The opening of the gauge-cocks may be sufficient.

When the boiler is empty, take off manhole and handhole covers.

Clean the furnace and grates, and the combustion chamber. Remove all dust and soot from around the boiler shell.

When the boiler has cooled sufficiently, open the smoke-box front doors; scrape all dirt off the front and back of boiler, and scrape the tubes. Do not use water, as water makes the soot cling to the cold metal.

The interior of the boiler should be washed thoroughly with a strong stream of water. If the boiler is still hot, cold water should not be used as it causes uneven expansion.

External Inspection

The furnace and grates should be closely examined, and also the brick work of the side walls for deterioration and cracks. The condition of the boiler shell in fire-tube boilers and the tube in water-tube boilers should be examined carefully for bags and blisters, particularly where the hottest gases strike the boiler. Scrape each joint with the hammer, and note if there is any sign of leakage. Look carefully over the brick work beneath the lugs of fire-tube boiler, and see that the plates or rollers that the rear lugs rest on are in such condition as to allow free movement of the boiler due to expansion. The same care should be taken in inspecting the supports of suspended boilers. See that these supports are protected from damage due to excessive heat.

Where forced draft is used, the air ducts should be carefully inspected for leaks, particularly where the air duct is contained within the boiler setting.

If the boiler is of the water-tube type, the baffling between the tube for directing the path of the gases should be carefully examined and care taken that there are no serious leaks, allowing short circuiting of the gases taking place and thus decreasing the efficiency of the boiler.

The blow-off pipe and valves and the method of protecting same should be given careful inspection, as leaks are very liable to occur at this point.

The covering on top of the boiler should be carefully examined, and all cracks attended to. Care should be taken that no drips from the safety-valve and piping are constantly falling on top of boiler covering or metal, as they cause corrosion.

The brick arch at the back should be examined, and it should be seen to that it is not allowed to touch the boiler, and is of such a height that the water-level in the boiler cannot fall below the level of the arch; otherwise, the hot gases may burn the shell.

The safety-valve, water-column and all valves and piping leading to and from the boiler should be inspected, and the steam gauge should be tested with a standard gauge; and if found not reading correctly, should be made to do so.

Have a helper hold a light at one end of each tube while you are examining the tube from the other end. Look for piles of soot and dirt in fire-tube boilers and scale in water-tube boilers; and as far as possible look for any corrosion in the tube, particularly at the ends, and if there are any signs of bags or blisters.

Internal Inspection

Before making the internal inspection of the boiler BE SURE THAT:—

(1) The main stop-valve is tightly closed.

(2) The automatic non-return valve is screwed down.

(3) The blow-off valves are closed.

(4) The feed-water valves are closed.

(5) The water tenders or firemen know you are in the boiler.

Upon entering the drum of a water-tube boiler, note the thickness or character of the scale deposits, and look for evidence of oil along the water-line. Chip away the scale at every seam, note the conditions of the rivet heads, and look for evidences of corrosion or grooving. If of the Heine or Edgmoor type examine the throat stays, and by holding the light down into the waterleg, note the condition of the stay-bolts. Inspect the dry-pipe, deflection-plate and mud-drum. Examine the connections to the water-column, and see that the pipes are clear.

Examine the stay-bolts. Tap them with the hammer to see if they are tight. Examine the handhole cap-seats, noting whether any are cut or grooved.

Examine the outlets from the boiler to the safety-valve and main steam-pipe for signs of grooving and pitting.

Examine the feed-pipe carefully. If feed-pipe is perforated, care should be taken to clear all holes of scale. Make sure it is properly suspended and not rubbing any tubes. Also that its interior is free of dirt and scale. Also the pipes leading to the water-column should have attention. Make sure they are placed in the proper position and are clean.

The tubes and shell of a fire-tube boiler should be gone over carefully and any pitting or corrosion carefully noted. Where much corrosion is noted on the shell, careful measurement of the thickness of the remaining plate should be taken.

Stays should be examined for corrosion and tapped with a hammer to see if they are tight.

Where scale is found in any thickness, particularly on the bottom of the shell, remove it and examine the metal carefully for bulges, for the scale will keep the water away from the metal, allowing it to become so hot that it stretches and forms a bag.

Where fusible plugs are installed, they should be examined both inside and outside of boiler. They should be scraped clean, and if showing any signs of deterioration, they should be renewed.

In water-tube boilers where mechanical soot blowers are in use, extra precaution should be taken to examine the tubes where deterioration may have taken place due to the impinging of the steam jet, and care should be taken that the nozzles are so set that this cannot occur.

The examiner should have his helper operate the mechanism to ascertain if the limit stops are set in correct position. Care should be taken that the valves leading to the blower are tight, and that only dry steam is used to blow the tubes.

Fig. 16. Horizontal Return Tubular Boiler. Note allocation of stays.

ENGINES

STEAM ENGINES

Energy may exist in different forms, such as heat, light, electricity and mechanical energy. Energy in one form is convertible into energy of another form, and the purpose of the engine, whether it uses steam or gas, is to convert heat energy into mechanical energy.

The history of the steam engine has been given many times and we feel there is no need of repeating it here. The engine consists of a cylinder in which a piston is placed, this piston being capable of being moved from end to end of the cylinder by means of suitable connecting links known as the piston rod and connecting rod. The piston is connected through a crank pin to a wheel. Steam is allowed to flow into the cylinder at one end. This steam presses against the piston, driving it forward, which in turn drives the fly wheel around. The steam in doing this work gives up the heat energy stored within it which is transformed to mechanical energy in driving the wheel.

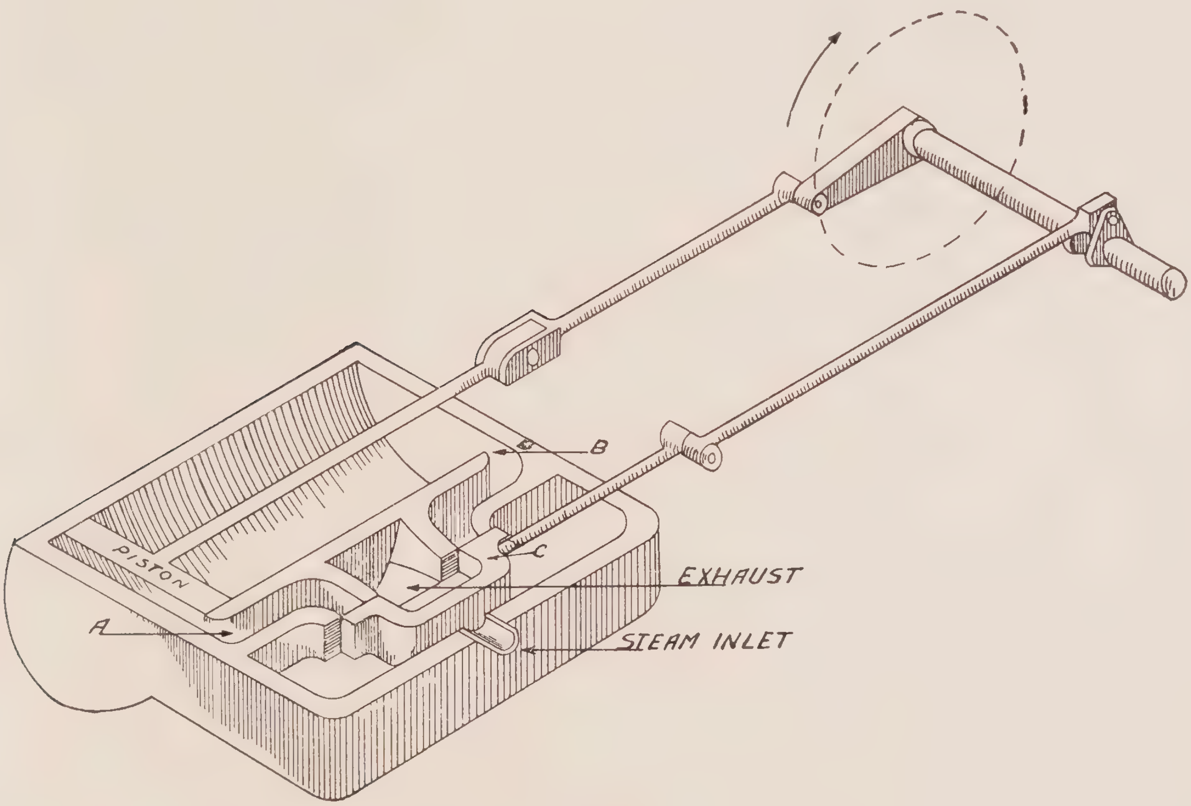


FIG. 17. Diagrammatical sectional view of plain slide valve engine.

When the piston has reached the other end of the cylinder from which it started, it must naturally stop, unless some means are employed to push it to the end it started from again. This is accomplished by the slide valve which slides over two ports—see A and B shown in Fig. 17; one leading to each end of the cylinder. The valve C allows steam to

enter at one port at a time, first on one side of the piston while it travels in one direction, and then the valve shifts, allowing steam on the other side of the piston, which pushes it back. This reciprocating motion through the connecting links causes the fly wheel to revolve on its shaft. At the same time the valve opens one port to allow steam to enter the cylinder to do work, its movement also opens the other port to the atmosphere, and allows the steam that was used to drive the piston in the opposite direction, to escape. This is known as the exhaust.

Upon studying the engine, it will be noted that when the piston has reached the end of its stroke, or in other words has been pushed to the extreme end of the cylinder, that the piston rod, connecting rod, and crank shaft are all in a straight line, therefore, any pressure exerted on the piston will simply push against the fly wheel shaft and will have no tendency to revolve the wheel. This condition comes into existence twice every revolution, and the engine is said to be on its dead centre. Unless some means are provided for carrying the engine over the dead centre, the engine would only make a half revolution and then stop.

To overcome this difficulty the fly wheel has been devised. During the time steam is acting upon the piston, energy is stored up in the wheel, which when the engine tends to slow down, is given up and is sufficient to carry the engine over the dead centre.

The fly wheel also has a steadying effect upon the speed of the engine during the revolution. It is also a convenient method of transferring the energy, through a belt running on its rim to the shafting of the machinery to be driven, and is quite frequently used in this way.

One of the first problems encountered by the beginner in steam engineering is that of the action of the slide valve. If one will go through the cycle of events covered by the valve, its action is easily understood.

To further our study of the slide valve let us take the simplest form of slide as shown in Fig. 18. We note that in Fig. 18A, the piston has travelled half the length of cylinder and is moving to the right; live steam is entering the cylinder through port A, and the exhaust steam is leaving the cylinder by ports B and O. It will also be noted that the main crank has just moved a quarter of a circle or 90 degrees, but will continue to move to the right another 90 degrees before it reverses its direction and starts to move towards the left. The crank driving the slide valve has reached its extreme travel to the right and is now about to move to the left. We now have the piston moving to right and the valve about to move to the left.

It will be noticed that by the time the piston has finished its stroke to the right, the valve has moved left sufficiently to close port A, Fig. 18B, shutting off the steam from the left hand side of the piston and closing the exhaust port on the right. A slight movement of the valve will allow the live steam to enter by port B, and the port A will be connected to exhaust port O and the steam entering through port B will drive the piston to the left as shown in Fig. 18C. Also, when the piston has reached the end of its stroke the valve will have moved to the right and opened port A to the steam which will again drive the piston to the right.

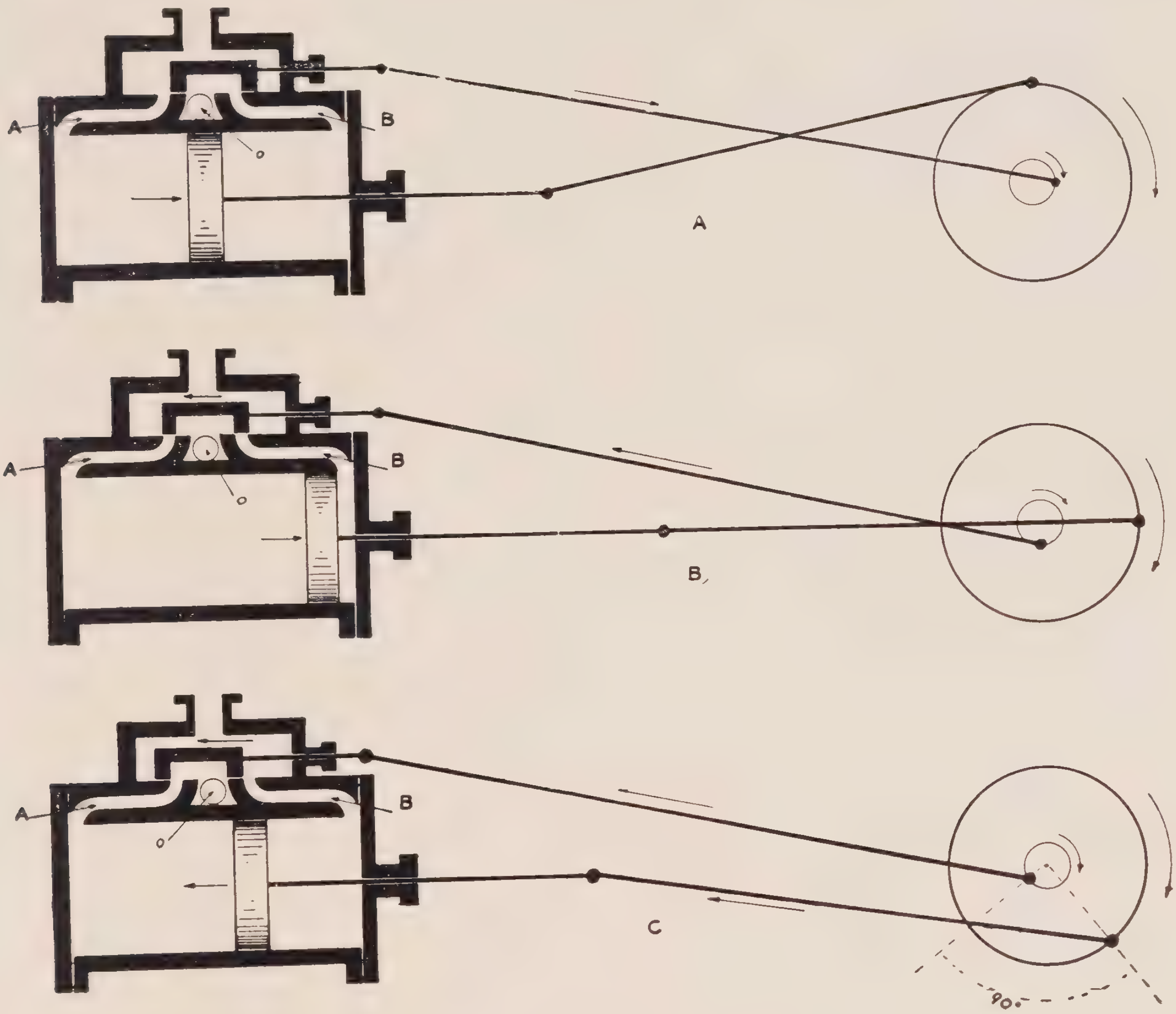


FIG. 18.

Why the Slide Valve Has Lap

It will be observed that a valve designed as in Fig. 18, allows live steam to flow into the cylinder during the whole length of the stroke. An engine with this type of valve would run, but it would not be economical, as no use is made of the expansive properties of steam.

If the steam could be shut off after the piston has travelled say half its stroke, the locked steam in the cylinder would expand and drive the piston the remainder of its stroke. The point of travel of the piston when the steam is shut off is known as the point of cut off. It can be readily seen that the earlier the point of cut off the less steam will be used by the engine. Of course, cut off must not be made too early or the engine will not be able to carry its load.

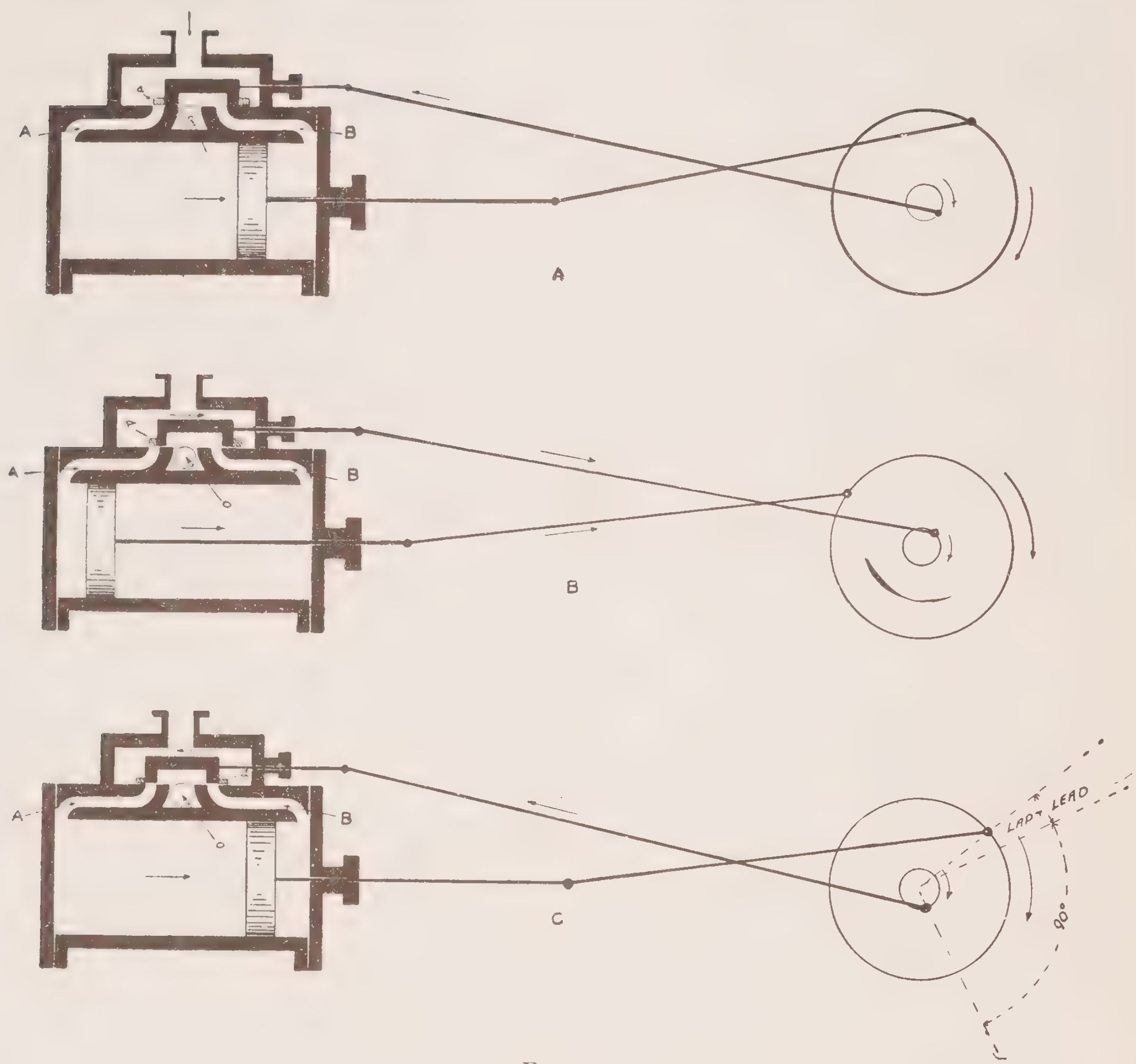


FIG. 19.

Earlier cut off can be accomplished by adding the lips "a" to the valve as shown in Fig. 19.

It will be noted that the port A, Fig. 19A, is closed before the piston has reached the end of its stroke, and therefore the enclosed steam must cause the piston to complete its stroke. In a like manner the steam will be cut off when the piston is travelling in the opposite direction.

In our discussion of the valve without the lip, we found that the correct position of the valve crank was 90 degrees ahead of the piston crank, but now by the adding of the lip and in referring to Fig. 19B, we find that at the beginning of the piston stroke the piston must travel some distance before it gets steam, as the valve still closes the steam port. This would be objectionable as it would slow down or stop the engine, unless the engine had an extra heavy fly wheel.

To overcome the difficulty the valve crank is moved around on the shaft, so that when the piston is on dead centre the valve has moved far enough to be slightly open. This slight opening is known as the "lead" of the valve.

We have spoken of the lip that was added to the valve. This part is called the "lap of the valve," and it is the amount of metal that extends past the outer edge of the port when the valve is in central position.

The hatched portion "a" in Fig. 19C, shows the lap of the valve. The correct position of the valve crank is 90 degrees plus the lap and lead in advance of the piston crank.

We have used the expression valve crank in our description. In common practice this crank is in the form of an eccentric.

Clearance and Cushioning

By studying Fig. 19C it will be noticed that the valve has moved to such a position that the opening from port B to exhaust port O has been closed, although the piston has not yet quite completed its travel to the right. The valve has entrapped a small amount of exhaust steam which, as the piston advances, is compressed and creates a pressure.

The reason for entrapping the steam is to help to bring the piston gradually to rest and avoid shock when the piston has to stop at the end of its stroke. This is what is known as "cushioning" the piston.

The space into which the steam is compressed is the area between the piston when it reaches the end of its stroke and the cylinder head added to the area of port B. This is known as the cylinder clearance.

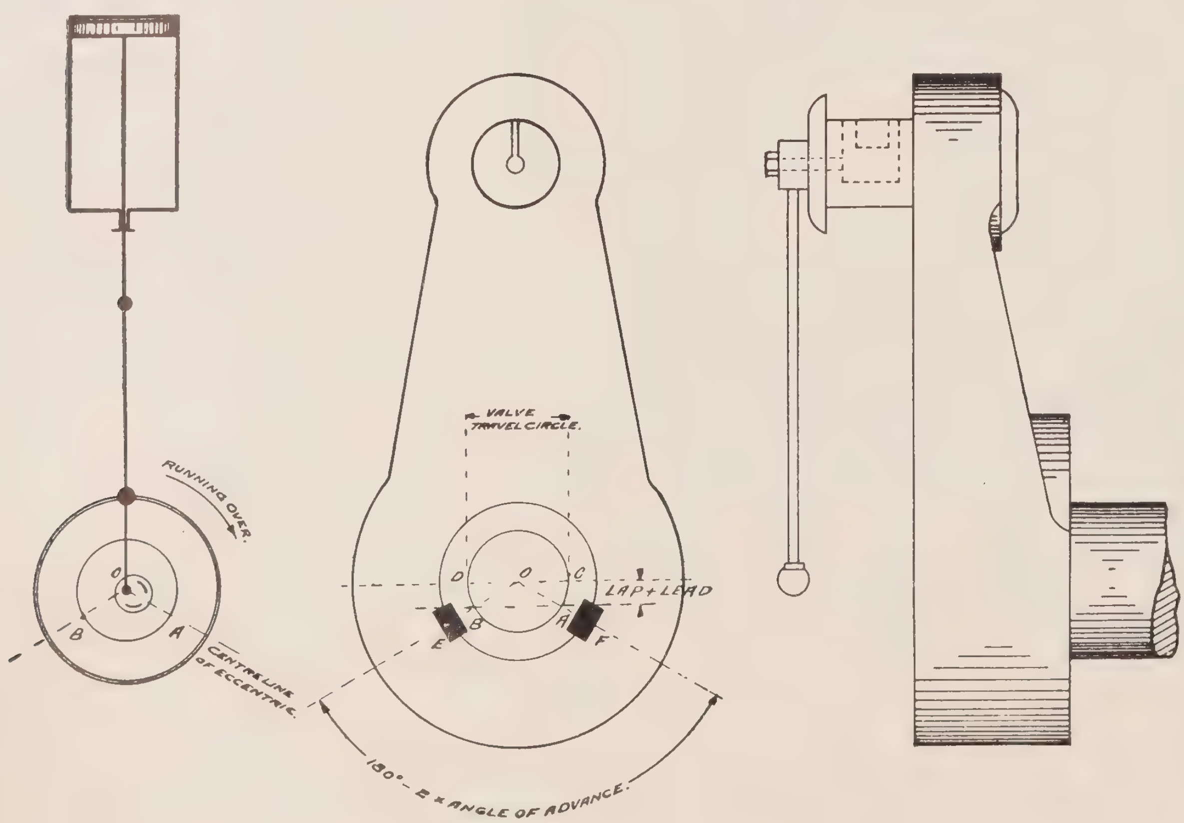


FIG. 20

VALVE SETTING

To Put an Engine on its Centre

To set the valves of an engine, no matter what type of valve is used, it is always necessary to put the engine on dead centre. A method of doing this is as follows:

Place the engine in a position where the piston will have nearly completed its outward stroke, and opposite some point on the cross-head, such as a corner, make a mark upon the guide. Against the rim of the pulley or crank-disk place a pointer, and mark a line with it on the pulley. Then turn the engine over the centre until the cross-head is again in the same position on its inward stroke. This will bring the crank as much below the centre as it was above it before. With the pointer in the same position as before, make a second mark on the pulley rim. Divide the distance between the marks in two and mark the middle point. Turn the engine until the pointer is opposite this middle point, and it will then be on its centre. To avoid errors that may arise from the looseness of crank-pin and wrist-pin bearings, the engine should be turned a little above the centre and then be brought up to it, so that the crank-pin will press against the same brass that it pressed when the first two marks were made.

To Set a Plain Slide Valve

To set the valve of a plain slide valve engine, first place the engine on dead centre, shift the eccentric on the shaft and set it as nearly as you can guess, somewhat more (be sure it is more) than a quarter turn, that is, 90 degrees ahead of the crank in the direction the engine is required to run, and fix it there.

Remove the valve cover and with a wooden wedge, measure the amount the valve lacks covering the port opening. If there is no opening and the piston is at the crank end of the cylinder, lengthen the valve rod by turning it until there is an opening, while if the piston is at the other end of the cylinder, shorten the valve rod. Next, turn the engine over until it is on the other dead centre, and measure the amount the valve lacks of fully covering the port leading to the other end of the cylinder. The amount of port opening of small engines when the piston is on dead centre, should be about the thickness of a knife blade. This opening is known as the lead of the valve.

If the two openings are exactly the same, then the valve rod is the correct length. If not, adjust the length of the rod until both openings are the same.

It may be found that the opening or lead, as it is called, may be too small or too great. To correct this, move the eccentric on the shaft while the engine is still on dead centre, until the valve is moved sufficiently to give the required lead. Make it fast to the shaft at this point. It is well to again put the engine on the other dead centre and check up if the lead is the same. Any minor defect in the setting can be noted and afterwards adjusted from an indicator card taken while the engine is running.

To Reverse Direction of Engines

We have already learned that the large part of the eccentric should be set 90 degrees plus the lap and lead in advance of the engine crank. Let us consider a valve without lap

or lead for the present. In this case the eccentric would lead the crank by just 90 degrees when the piston is on dead centre and the valve is just beginning to open the port nearest the piston. Now, if the engine is given a half revolution, then the valve is just exactly in the same position relative to the other port, and when steam enters it will drive the piston the opposite direction. It can be seen, then, to reverse the direction the engine will travel, it would only be necessary to remove the key or set screw from the eccentric disc, and hold it stationary while the engine was given a half revolution, or turned an angle of 180 degrees, when conditions would be exactly reversed and the engine would run the opposite direction. In actual practice it is easier to keep the engine stationary and move the eccentric, but it amounts to the same thing.

Now let us add lap and lead. The eccentric, to be correct for an engine running over should be in advance 90 degrees plus lap and lead. It, therefore, stands to reason that when running under, it should be in advance 90 degrees plus lap and lead, and therefore eccentric should be turned forward not 180 degrees, but only 180 degrees minus twice the sum of the lap and lead, as can be seen by studying Fig. 20. It will be noted the eccentric must be moved only from F to E.

Reversing Engines

As a rule stationary engines are only required to run in one direction, but there are other engines, such as the locomotive, that are continually being reversed. In these cases it would be impractical to stop and turn the eccentric around on the shaft each time. Other means have been devised to obtain the same results.

The Stephenson Link Motion

We have seen that by changing the eccentric from F to E (Fig. 20) the engine will run in the reverse direction. Now, supposing instead of changing the eccentric from F, another eccentric is added at E, and the rod between the eccentric and the valve is disconnected from the first eccentric and connected to the second eccentric; the engine would then run in the reverse direction. This is the principle upon which the Stephenson link motion is operated.

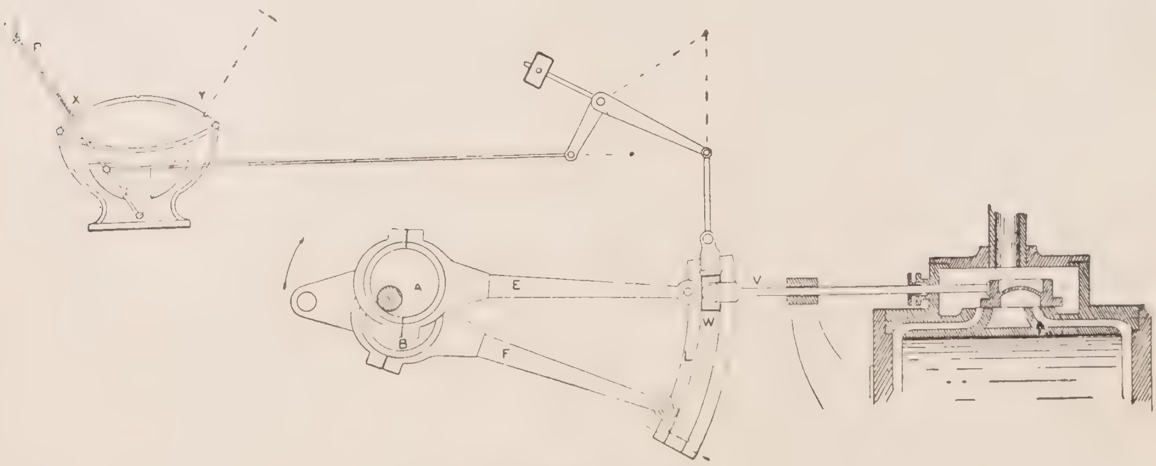


FIG. 21. Stephenson link motion

Fig. 21 shows an outline of the Stephenson link motion. The two eccentrics A and B will be noted, each having their respective eccentric rods E and F, which are connected to a slotted link L made in the form of an arc of a circle. In the centre of the link is a sliding block W connected to the valve stem V. By a movement of the hand lever P, the link L through the connecting rods, can be moved up and down, carrying the eccentric rods with it. In the diagram, rod E and rod V are in a straight line, therefore, eccentric A is controlling the motion of the slide valve in exactly the same manner as the eccentric of any simple engine would control it.

If, however, the hand lever is shifted from notch X to notch Y, then the eccentric rod F is brought in line with the valve rod V, and eccentric B would control the valve motion, and the direction of rotation of the engine would be reversed.

Supposing the hand lever is moved to the centre notch half way between X and Y, then valve rod V would be situated just half way between the eccentric rods F and E. If E moved in one direction, F would move equally in the other direction, with the result that valve rod V which is half way between them would have only a slight motion; the valve would not uncover the port except by the amount of the lead and the engine could not run.

We have seen that the valve has the greatest travel when the hand lever is in either notch X or Y, and least when in the centre notch. Now, if the lever were moved up to a point between X and the centre, the valve would have motion, but not as much as when the lever is at X. When the travel of the valve is decreased, cut off must take place earlier. This affords an opportunity of allowing the steam to be used more expansively and thereby effecting a saving in steam.

A locomotive engineer is well aware of this fact. After he gets his train well under way he will "hook up," that is, move the lever nearer to the centre, getting an earlier cut off and saving coal.

The Walschaert Reversing Gear

It has already been learned that when a valve has neither lap nor lead, the correct position of the eccentric in rotation to the crank is 90 degrees in advance. To reverse an engine with this type of valve, the eccentric must be moved 180 degrees or exactly opposite on the shaft.

The Walschaert reversing valve gear has but one eccentric which is set exactly 90 degrees ahead of the crank. To reverse, instead of shifting the eccentric, a radial limb oscillating about centre C, as shown in Fig. 22, is used. It can be seen that when the shifting intermediate rod F is in the position K D, the eccentric must follow the crank, but when the rod is changed to the position K B, the eccentric will lead the crank.

If rod F were connected directly to the valve rod G at L, and the valve had neither lap nor lead, the engine would run equally well in either direction, depending upon the position of D or B of rod F.

We know, however, that for economical operating reasons, a valve must have lap and lead. To secure a further motion of the valve required for lap and lead, the rod M L is

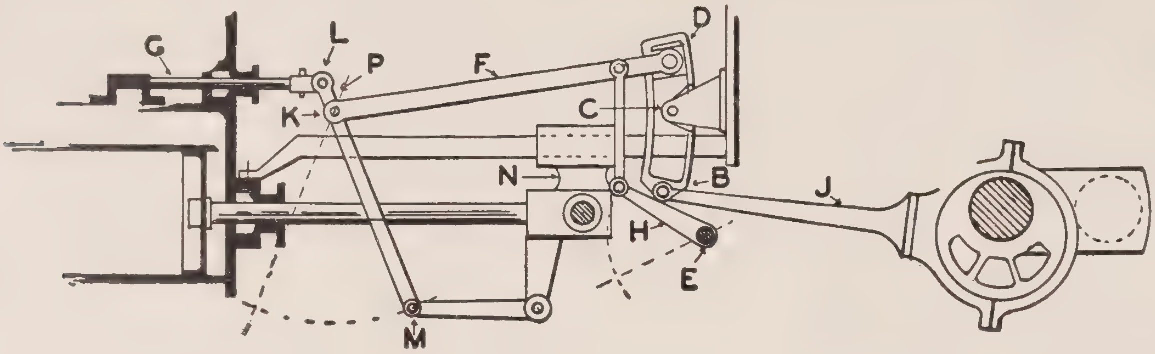


Fig. 22. Walschaert valve motion as applied to stationary engine.

connected and made to oscillate from the main piston rod, about the centre K, which is the end of the intermediate rod F.

The motion L P transmitted to the rod where it is connected to the valve rod is made equal to just twice the sum of the lap plus the lead. It can therefore be seen that when the piston has reached dead centre, the valve has been moved an amount equal to the lap plus the lead, due to the motion derived from the piston rod, while it has received the rest of its motion from the eccentric.

If the rod F is moved to the point C, then the valve would have no motion due to the eccentric, and its only motion would be twice the lap plus the lead as conveyed to it from the piston rod.

The length of the stroke of the valve and therefore the point of cut off, can be regulated by the position of the rod F relative to the link D B. The position of rod F is controlled by the engineer through suitable link motion H and E.

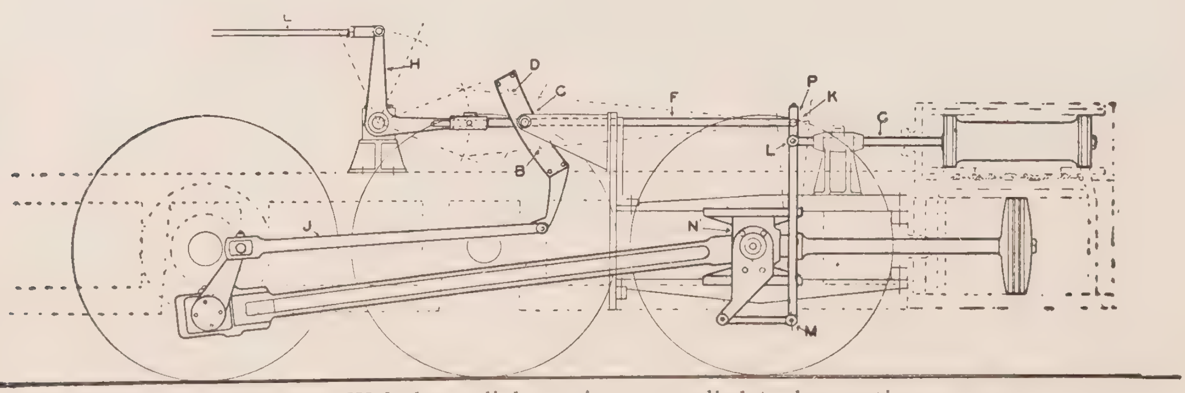


Fig. 23. Walschaert link motion as applied to locomotives.

The Walschaert valve gear has the advantage that its parts are considerably lighter than the Stephenson link motion, and particularly when used in connection with locomotives, are more accessible for repairs and it will also be noticed that the link D B is curved to a radius equal to L C, and thus the lead is always the same, irrespective of the point of cut off. This is not true of the Stephenson link motion.

The Walshaert gear as applied to locomotives, is shown in Fig. 23. It will be noted that the eccentric is replaced by a crank on the outer end of the shaft and the slide valve is replaced by a piston valve.

It will be noted that the lettering used above applies equally well to either diagram.

The Woolf Reversing Gear

A simple reversing gear using only one eccentric, and used quite extensively on traction engines, is shown in Fig. 24.

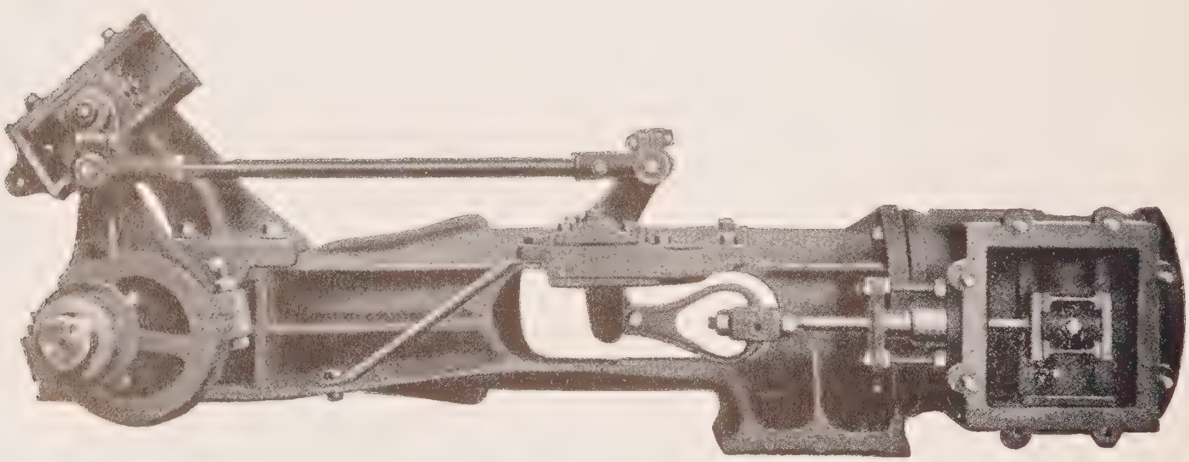


Fig. 24. Woolf reversing gear.

Fig. 25 is a diagram showing the manner in which the valve A_4 is reversed.

A_1 is a guide, pivoted at the centre and held in position by lever A. Travelling in the guide is a block attached to the arm of the eccentric, while link motion A_2, A_3, A_4, connects the eccentric arm to the slide valve.

The diagram shows the guide A in an inclined position, therefore, when the main shaft revolves the eccentric, the point A_2 must assume a horizontal motion as well as a vertical motion. The horizontal motion of point A_2 is conveyed through links to the valve, and the valve slides to and fro, just like the ordinary slide valve. The diagram shows steam entering the right hand of the piston, and exhausting at the left hand side, thereby causing the piston to travel from right to left.

Now, let lever A be moved to the position B, which will cause A_1 to move to position B_1 and A_2 to B_2 and A_3 to B_3 and A_4 to B_4. When A_4 is moved to B_4, it will be noted that

the valve is just in the reverse position, relative to the port, and steam is entering the left hand side and exhausting at the right hand side, causing the piston to move from left to right, and thus the engine is reversed.

The distribution of steam may not be just the same when the engine is running forward as when backward, but can be made nearly so by placing the guide a little forward of the centre of the shaft. This gear makes a very simple rigid reversing mechanism for small engines, which does not always get the care a more complicated system would require.

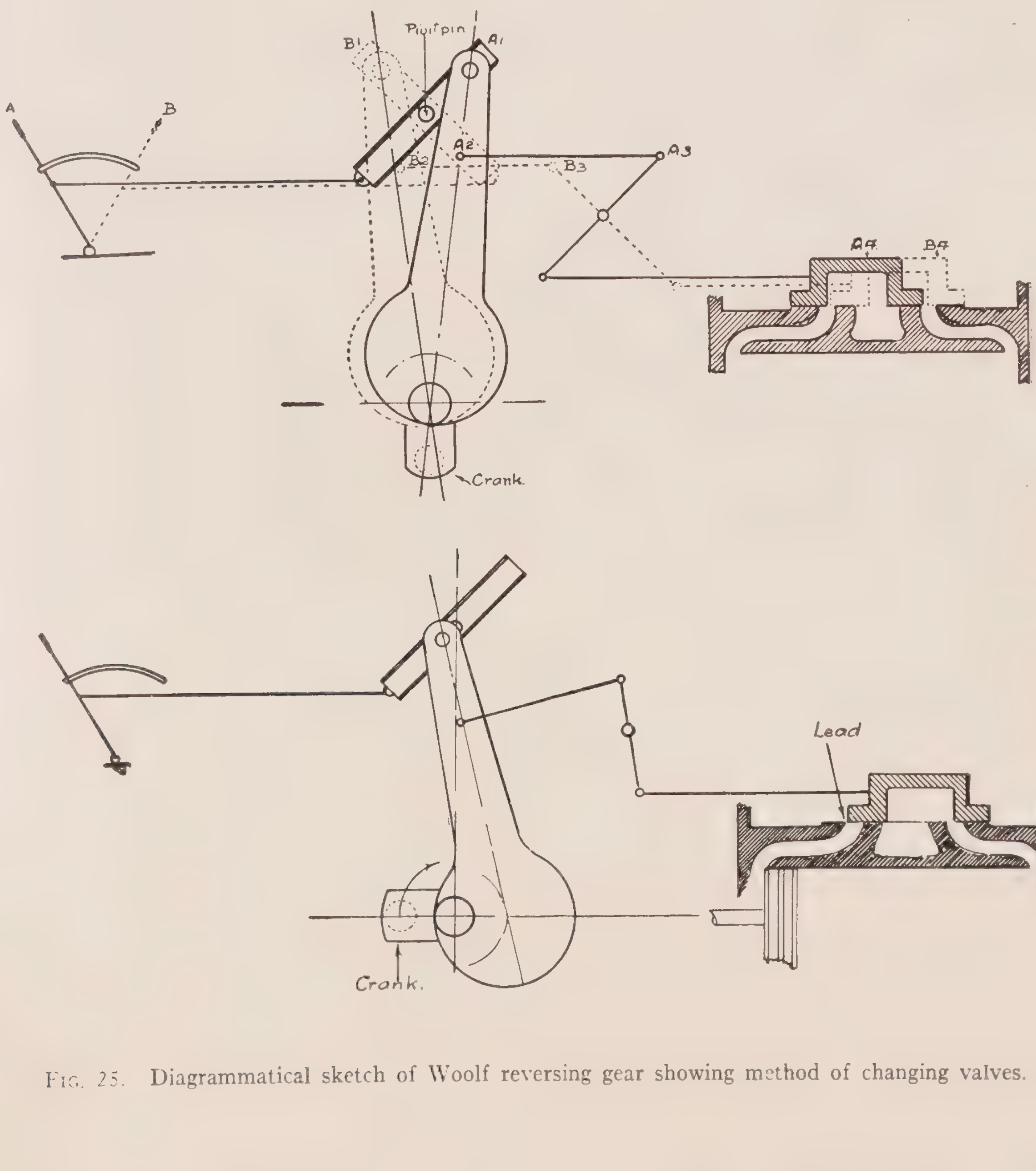


FIG. 25. Diagrammatical sketch of Woolf reversing gear showing method of changing valves.

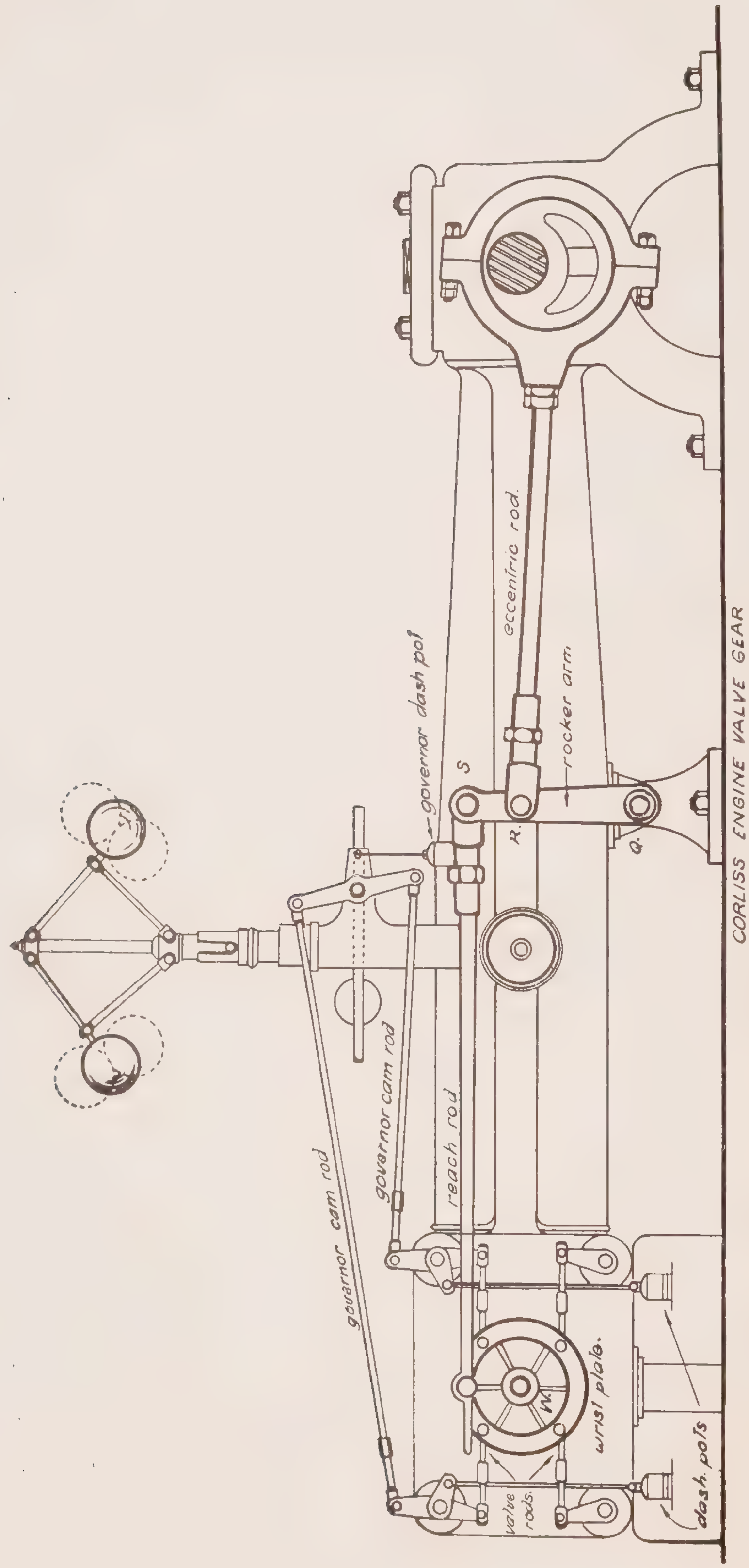


Fig. 26. Corliss engine.

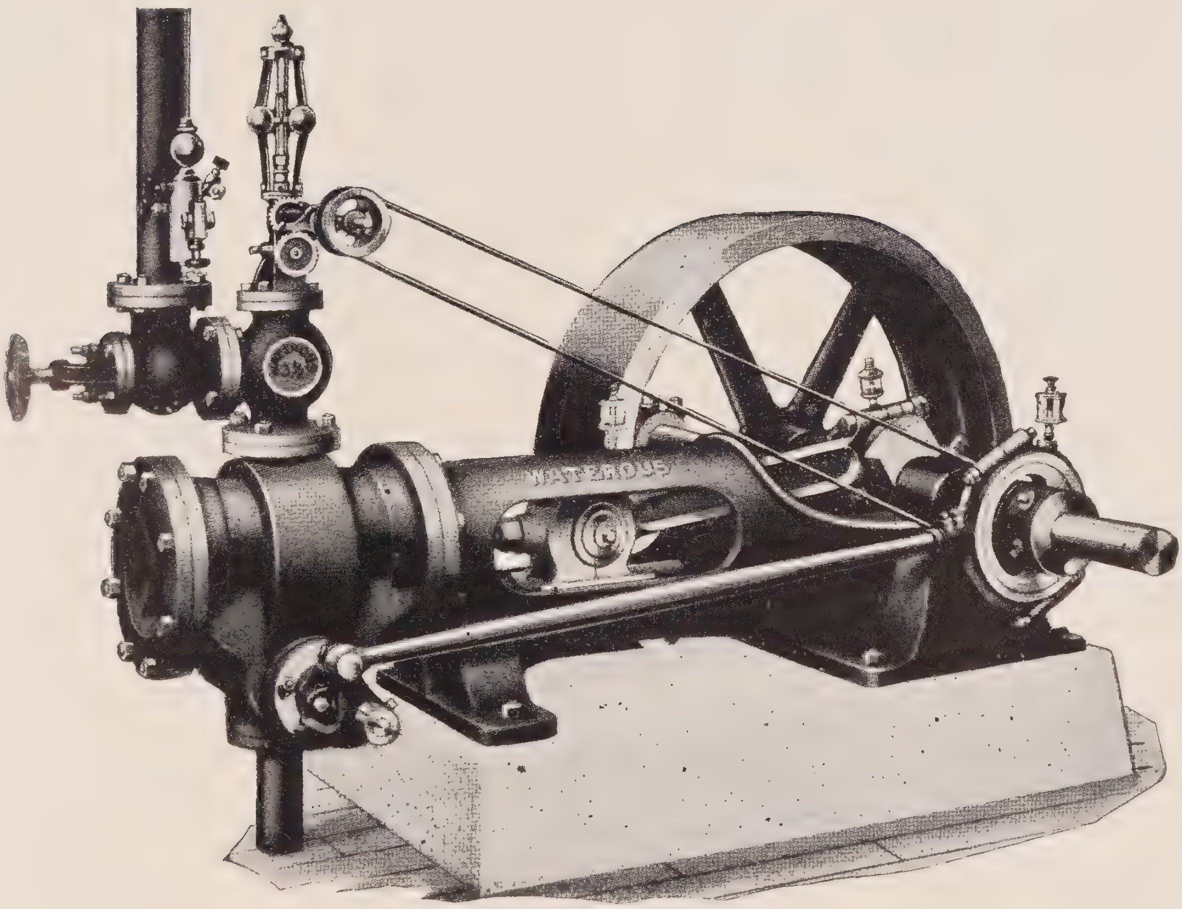


Fig. 27.

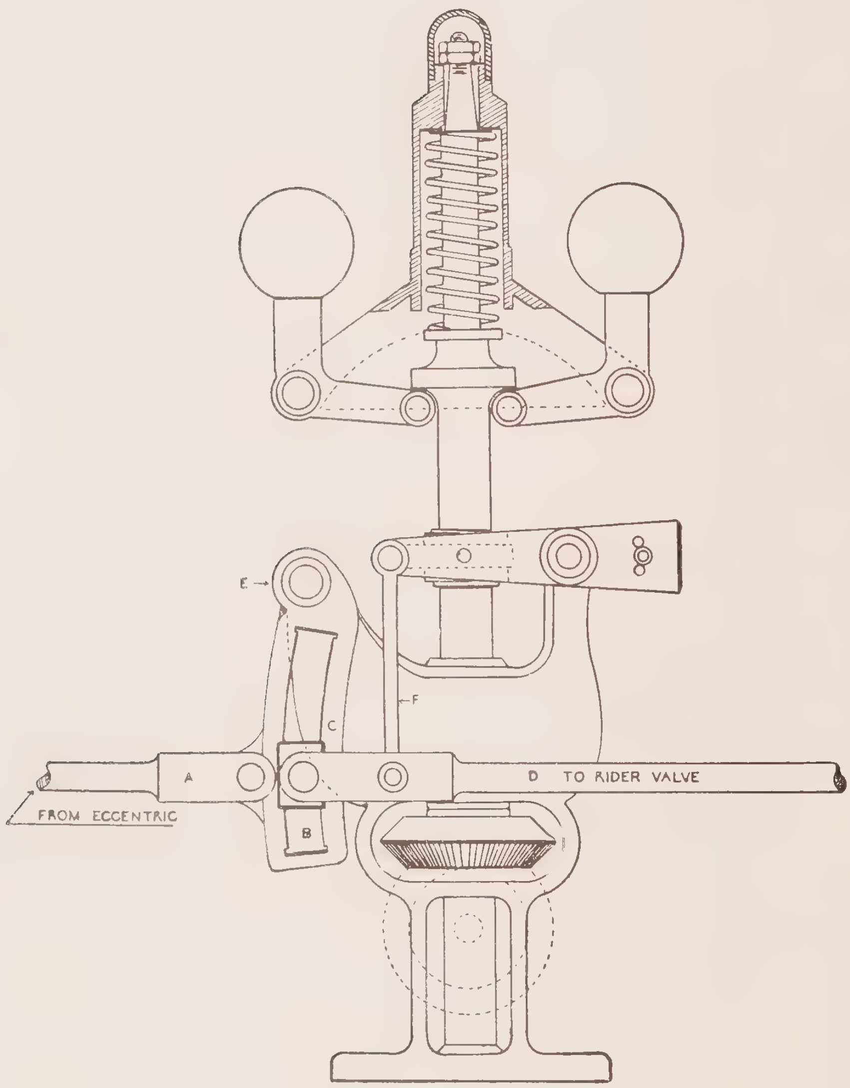


FIG. 28. Hartnell governor.

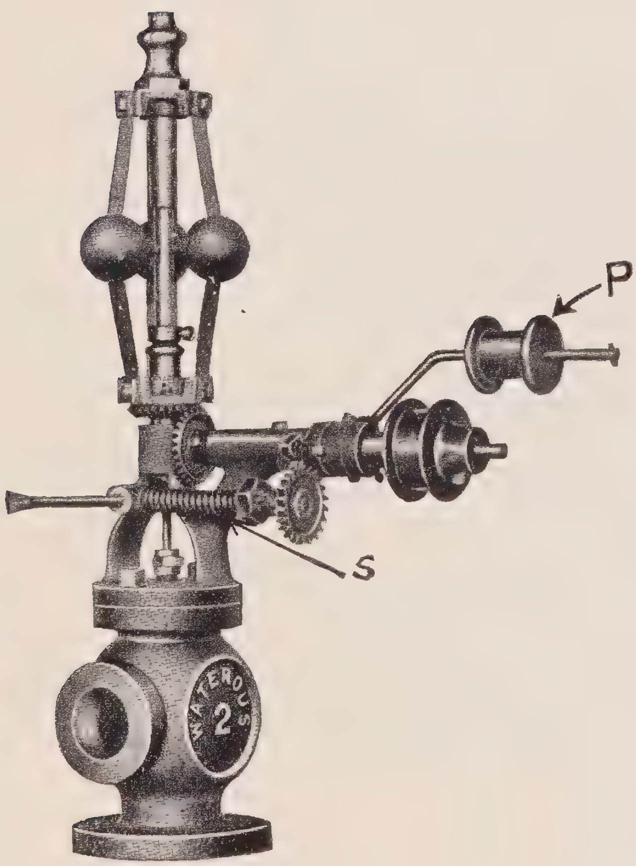


FIG. 29. Pickering governor.

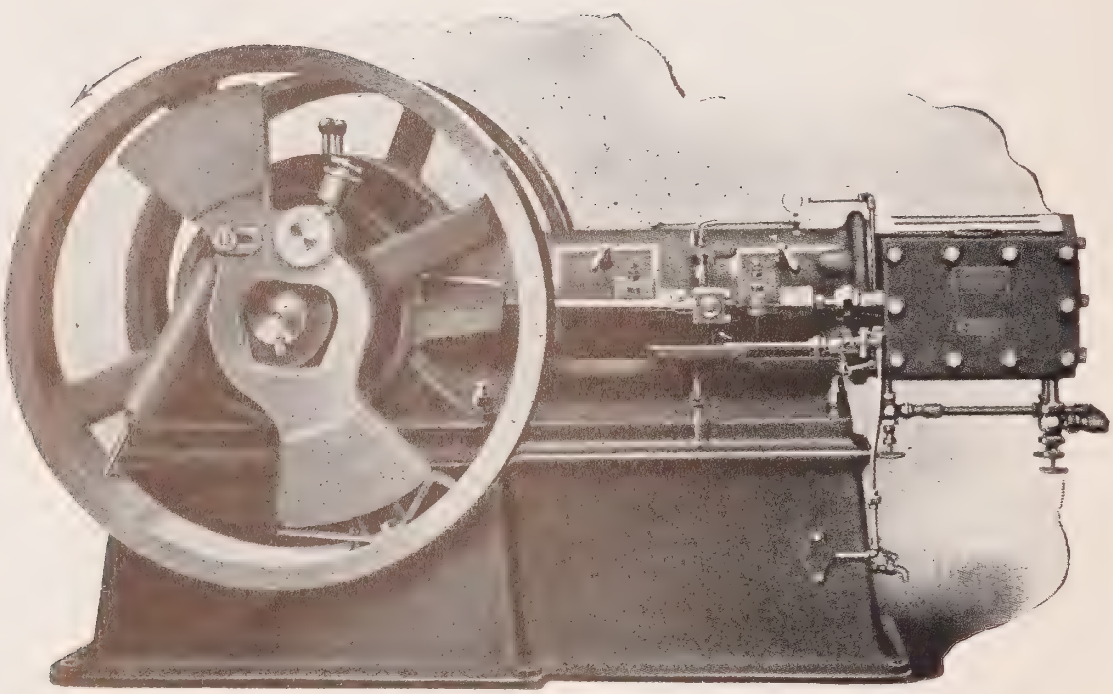


FIG. 30. Engine equipped with Rites inertia governor.

PUMPS

PUMPS

Head Pressure on Pumps

The function of a pump is that of raising water or other liquid from a lower to a higher level. The pump accomplishes this in two ways, namely: by forcing the liquid from its cylinders by means of its pistons or propellers, and by what is commonly called "suction". Suction means, first, the forcing of air out of the cylinder, until the pump becomes "primed" (which means, until the water has risen in the suction line and entered the pump); then, after the pump is primed, it forces the water out of the cylinders and more water is drawn into them, or, we should say, forced in, by atmospheric pressure.

The reason water rises in the suction line to the pump, is that, as the piston of the pump moves forward, forcing out the water it contains, it leaves a partially empty space in which the pressure is less than the atmospheric pressure, and weight of the air on the top of the water in the well forces the water up the pipe.

It is due to the work of the pump that the liquid is raised from the level of top of the water in well, to the top of the level of the water in the tank into which the pipe is discharging.

As noted in Fig. 31, the head of water is the 5 feet suction head, plus the 15 feet discharge head, or, a total head of 20 feet.

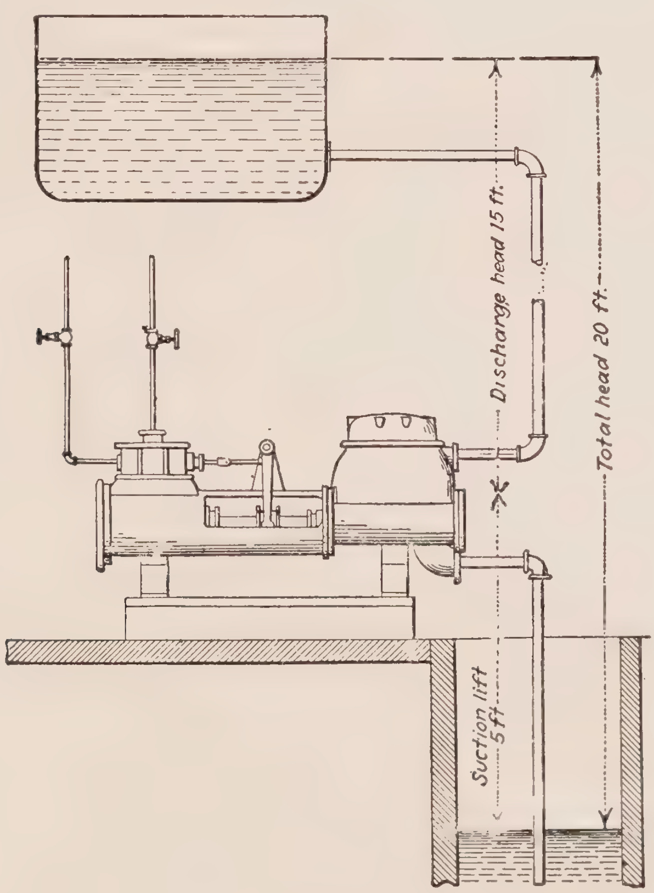


Fig. 31.

If, supposing the water, instead of being pumped into an open tank, is being forced into a boiler under pressure, then the pumps overcome the head due to the distance from the level of water in the well to the cylinders of the pump, the head due to the vertical distance from the pump to the point of entry to the boiler, and the head due to pressure in the boiler. One pound of pressure as exerted in the boiler is equal to the pressure exerted by a column of water about 2¼ feet high (27.68 inches to be more nearly correct).

Returning to Fig. 31, if instead of pumping into a tank as shown, it was pumping into a boiler carrying 100 pounds pressure, then the head which the pump must overcome would be:

$$5 + 15 + (100 \times 2.25) = 245 \text{ feet head.}$$

In addition to the above, the pump must overcome the friction of the water in the pipe, which quantity would depend upon the size of the pipe, the number of elbows, turns and foot-valve (if used) and the velocity of the water. This quantity should be relatively small.

Why Water Cylinder of Boiler Feed is Smaller than the Steam Cylinder

In our example in a preceding article, we showed that, in addition to friction, the pump had to operate against a head equal to a column of water 245 feet high.

Now, as stated, a column of water about 2¼ feet high exerts a pressure of 1 pound per square inch. Therefore, 245 feet would exert a pressure of:

$$\frac{245}{2.25} = 108 \text{ pounds per square inch.}$$

This shows that the water pressure holding the water piston from moving forward, is 108 pounds per square inch of piston area, while the steam pressure is only 100 pounds per square inch, tending to drive the piston forward.

Hence, if the steam piston of a boiler feed pump has not a considerably greater square inch area than the water piston, it cannot possibly move forward and push water into the boiler.

Pump Valves

No matter what size the pump may be, the valves are always small, being somewhere between two and four inches in diameter. Naturally, large pumps have more valves than small ones. The reason for using small valves is that the valves must close quickly or the water would rush back when the piston reaches the end of its stroke. The lift of a small valve presents a proportionately larger surface of discharge with the same lift than a large valve, therefore, it is better to use many valves with small lift rather than few valves with large lift. The height of the lift of the valve determines the length of time the valve will take to close.

The valves of a pump are of the spring-loader flat-disc type. It is usual to use a disc composed of a soft rubber compound for cold water, and for hot water, a disc of hard rubber, compressed fibre or a special metallic alloy.

The discs are held in place on their seats by spiral springs, each held by a bolt through the centre, as shown in Fig. 32.

Pumps must have two groups of valves, commonly called the suction valves and the discharge valves. The suction valves open toward the cylinder and the discharge valves away from the cylinder.

When the piston moves away from the cylinder head, the water flows through the suction valves into the cylinder, filling it. The piston then changes direction, the suction valves close and the discharge valves are forced open by the water being discharged from the cylinder. When the piston comes to rest at the end of its stroke, the discharge valves close.

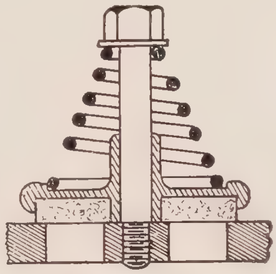


FIG. 32. Pump valve.

Why Reciprocating Pumps Have Air Chambers

It will be noticed that many reciprocating pumps have domes connected to the discharge, while large pumps have a dome on both the discharge and suction. The reason for this is to absorb shock and give an even flow of water in the pipe.

When the piston reaches the end of its stroke it stops and then starts back, therefore the flow of water in the discharge pipe stops, and when the piston moves forward again, the flow of water takes place. This causes a pulsating flow of water. To overcome this an air chamber is provided, which is filled with entrapped air. As the piston moves forward, a portion of the water enters this dome, compressing the air, and when the piston comes to rest, the compressed air forces the water out of the chamber, thus creating a more even flow in the discharge line. Duplex pumps will give a more even flow of water than a single cylinder pump, as one piston is always forcing water into the line.

The dome on the suction pipe forms a vacuum chamber. When the piston is moving, water fills the chamber and when the piston stops, the vacuum helps to hold the water from flowing from the pipe.

Centrifugal pumps have no air chamber because they keep a continuous flow of water.

Setting Steam Valves of Duplex Pumps

When a direct-acting duplex steam pump suddenly takes to running lame or pounding, the operator's first impression is that the steam valve gear is at fault. The pump may short stroke from too much friction of pistons or piston-rod packing, or may pound from

loss of cushion, or from running the pump faster than usual and from a change in head pressure. When regulation of the cushioning is not provided for, as is the case with most small pumps, nothing remains but readjustment of the valve gear.

If new piston rods have been provided or if the "spools" which are clamped or keyed to the rods for moving the rocker arms, have moved, the first step would be to locate the spools, to bring the rockers square with the rods when each steam piston is in the middle of its stroke. For this purpose, the packing should be removed from the piston-rod stuffing boxes, and the glands should be screwed up tightly. The outboard cylinder heads being removed, the steam pistons should be pushed up solidly against the inside heads. Then a line should be scribed on each rod, flush with the faces of the water end glands or gland nuts. The head of steam cylinders should then be replaced, and with the heads of the water cylinder removed, the water pistons should be pushed into the cylinders until the steam pistons are brought up solidly against the outboard heads of the steam cylinders, and each rod be scribed at the face of the same gland as before.

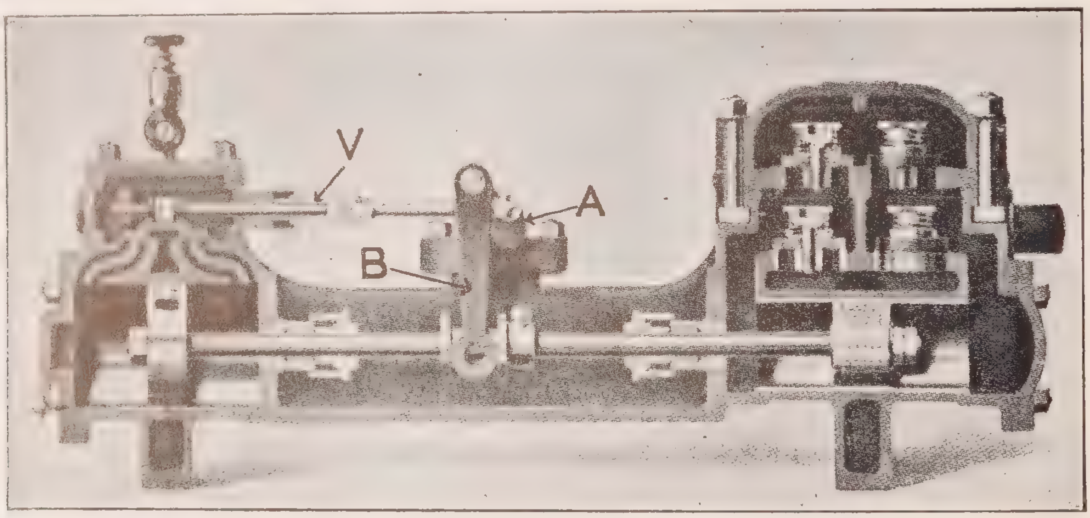


Fig. 33. Sectional view of reciprocating pump.

Then make another mark on each rod, halfway between the marks, and move the pistons back until the middle marks come even with the faces of the glands from which the first marks were made on the rods.

This places the steam pistons at mid-stroke between the striking points. The spools or crossheads then should be slipped along the rods until the rocker arms stand square with the rods, as shown in Fig. 33, and with the rockers in that position, the spools or crossheads should be set firmly on the rods.

Next, remove the steam-chest cover, and place the slide valves exactly in the centre over the steam ports, when, for each valve, the valve-stem lost-motion clearance should be the same for movement of the rocker in either direction, without moving the valve.

Figs. 34 and 35 show how the clearance is obtained in small pumps. A valve rod nut a, is placed on the rod b, the nut being thinner than the space C between the jaws of

the valve. There should be the same clearance J on each side of the nut. If there is not the same clearance on each side, remove the rocker pin from the end of the valve stem shown at V, Fig. 33, and with the valve central over the ports, screw the valve rod through the nut until the eye on the valve-rod head can be brought in line with the eye of the link from its rocker A, Fig. 33, then slip the valve-rod head pin in place and the valve is set. With this type of lost motion adjustment, the total amount of lost motion is fixed and cannot be changed except by inserting a nut of different thickness.

Fig. 35 shows a method of equalizing and also adjusting, the amount of lost motion J, without disturbing the connection outside of the steam chest. With lost motion obtained as shown in Figs. 34 and 35, the total lost motion of the former setting should be gauged before making any adjustment, and this should be equalized to give the same clearance J, at each end, when the valves and rockers are central.

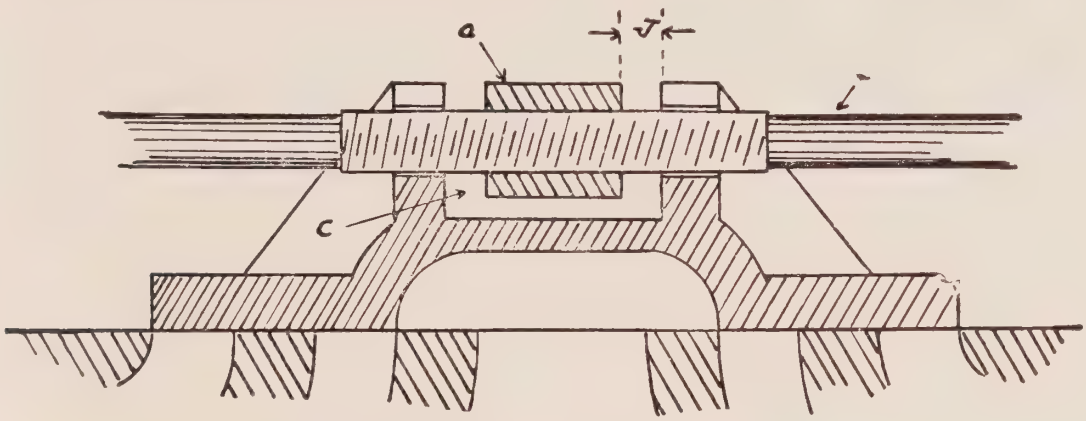


FIG. 34.

When the clearances have been equalized, and before closing up the steam chest, move one of the valves as far as it will go to one side, so that the pump may be started when steam is admitted to the steam chest.

Cushion of Duplex Pump

As shown in the sectional view, Fig. 33, the steam cylinder of a duplex steam pump

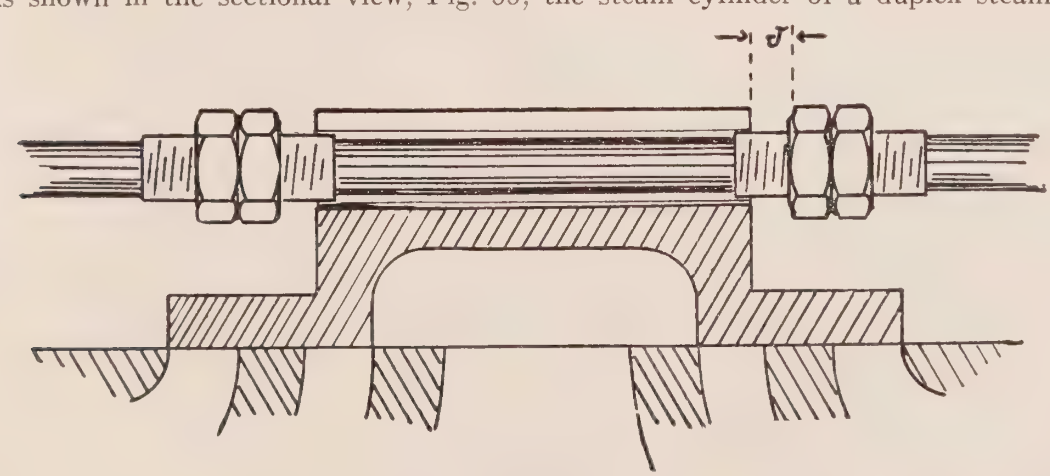


FIG. 35.

is provided with two sets of ports at each end. The outer ports, or those next to the ends of the steam cylinder, are steam ports, which are for steam admission only, and guide the steam into the clearance space behind the piston. The inner ports, which terminate a short distance from the cylinder heads, are the exhaust ports. The piston, in approaching the end of a stroke, covers the exhaust port. Exhaust steam then remaining in the end of the cylinder and steam port, is compressed by the piston, and the distance from the outer edge of the exhaust port to the head, forms the cushion. There is no means of changing this distance to adjust the cushion, but in some makes of pumps there is a passage between the ports, and the amount of opening of this passage is varied by what is known as a cushioning valve. This valve can be opened if the cushioning is too great, or closed if cushioning is insufficient.

Single Acting Pumps

In steam pumps, the absence of rotating parts prevents the use of eccentrics to move the valve, and some other method must be found. This difficulty in duplex pumps is easily overcome by making the pump mechanism of one pump govern the valves of the other by means of a rocker shaft, as described elsewhere. In single cylinder pumps other means must be found, and many ingenious valve gears have been devised. Space will not allow a description of them all, but the following gives a general idea of the principle in each, although details differ.

In addition to the main slide valve there will be found some sort of auxiliary piston

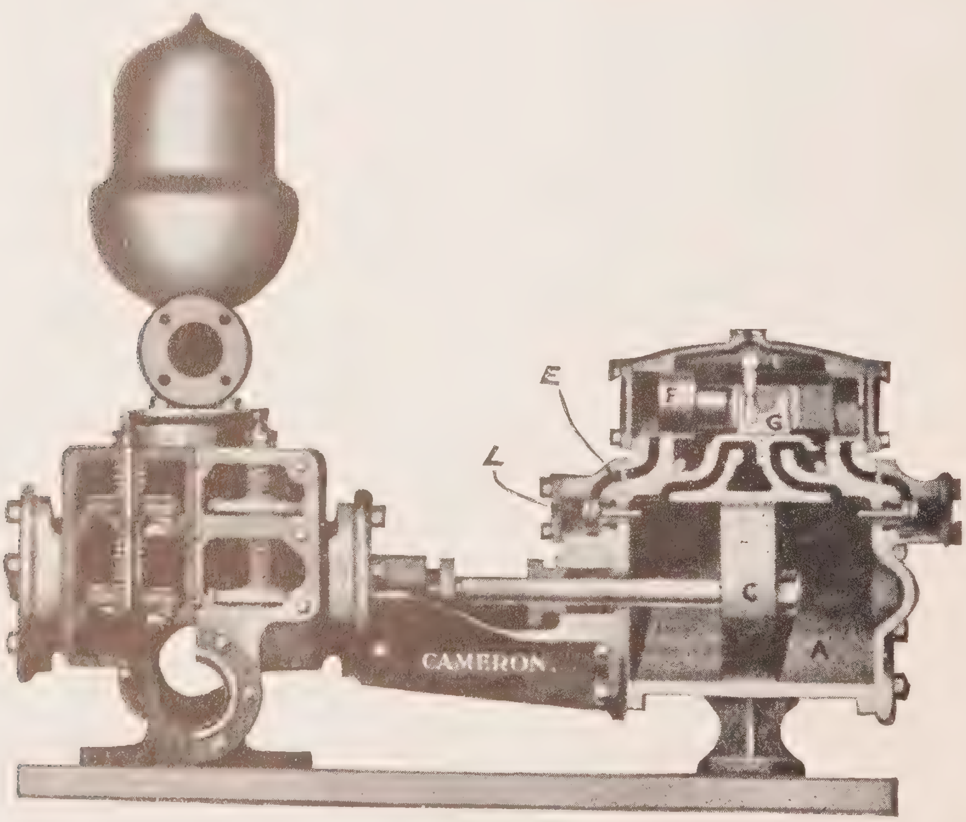


FIG. 36. Single cylinder pump.

connected to the main valve and moving in a cylinder formed in the valve chest. This piston is controlled by an auxiliary valve, operated by some suitable gear, by the main piston or piston rod. When the main piston has almost completed its stroke, the gearing becomes engaged and shifts the auxiliary valve, causing steam to be admitted to one end of the auxiliary piston and allowing steam to exhaust from the other end. The steam causes piston to move, which in turn moves the main valve. This reverses conditions in the main

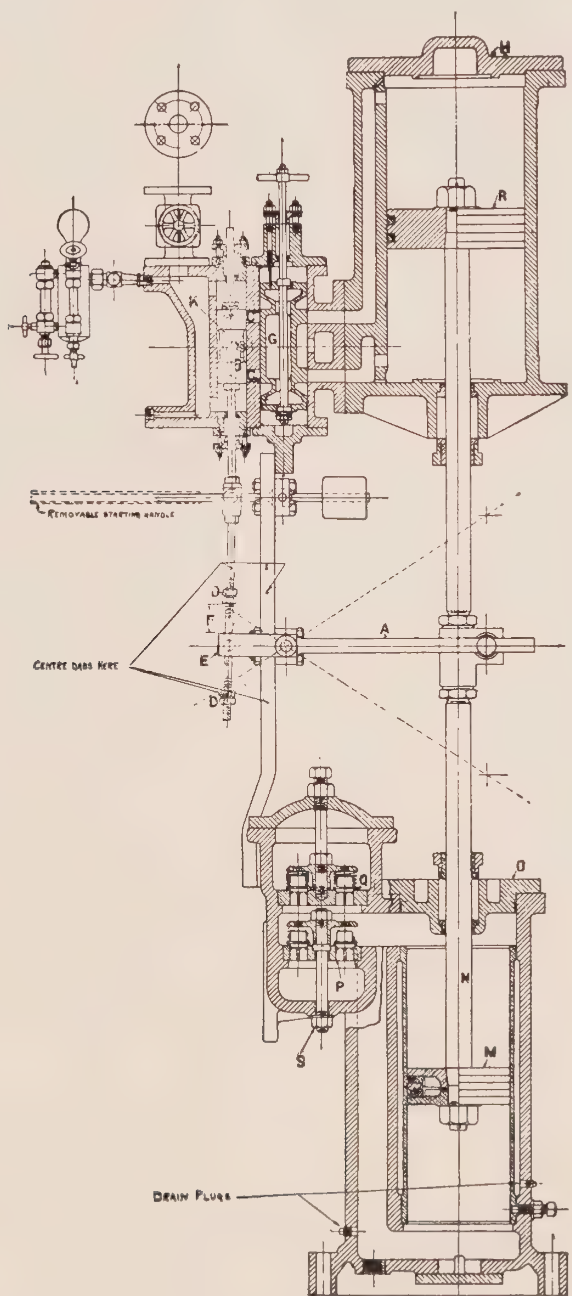


FIG. 37. Vertical single cylinder boiler feed pump.

cylinder, with the result that the main piston will move in the opposite direction until it has again reached the end of its stroke, when the operation will be repeated.

Fig. 36 is an example of the auxiliary valve type. It will be noted that the auxiliary valve L has a short stem projecting into the cylinder. When the main piston moves towards the end of its stroke, it comes in contact with the stem, forcing the valve back and opening the exhaust port E, and relieving the steam pressure from the end of auxiliary piston F. The steam pressure on the other end immediately pushes the auxiliary piston to the end of its cylinder, and the piston, being attached to the main valve, carries it with it, thus reversing conditions in the main cylinder.

Fig. 37 is a diagram of a vertical, direct acting pump, manufactured by Goldie-McCulloch Co. They issue the following instructions for the setting of the valves, and general care of this pump.

(a) Set the side levers A, in a horizontal position, as shown on cut.

(b) Set the pilot valve B, with outside edges overlapping steam ports C, the same amount at each end; this will be about $\frac{1}{16}$ inch.

(c) With the side levers A in horizontal position and the pilot valve covering steam ports as stated above, set the nuts D an equal distance off each side of the swing block E. This distance will vary according to the size and stroke of the pump. Leave the nuts loose and start the pump, bringing the nuts D closer to the swing block E, if a shorter stroke is required or if the pump knocks at end of stroke, and lengthening this same distance if a longer stroke is desired.

To Start Pump on Boiler Feed Service

1. Open the drain cocks.
2. See that pump is open to exhaust line.
3. See that valves on suction and discharge pipe line are open.
4. See that feed check valves on boiler are open.
5. Turn on steam gently; do not open valve full out.
6. Move pilot valve up and down for a few minutes with starting handle and when the pump is moving freely and steam cylinder is clear of water, close drain valves. *Note* that pilot valve B requires to be moved not more than ⅝ inch up or down (1¼ inches total travel in all); greater movement than this may altogether close the exhaust passage to cushion screw K, and prevent shuttle valve moving.

Cushion Screw K

This regulates the speed of movement of the shuttle valve and is usually about half a turn off its seat, but may require slightly different adjustment for varied conditions of running.

To remove any obstructions or scale that may form on end of screw or its seat, it is advisable to sometimes close cushion screw K hard down on its seat and then slack back to proper position.

The design and timing of the steam valve motion permits the pump to slow down at the end of each stroke, thus letting the water valves settle quietly on their seats without

shock and giving long life to the valves; the start of the return stroke is without jar or shock.

The pump moves with a steady slow speed, and, on account of this, and also on account of the slowing down of movement at ends of stroke and the special design of water valves and bucket, the efficiency is high.

The pilot or timing valve also acts as a cut-off valve, cutting off steam at .75 to .8 of stroke, allowing the steam to be used expansively and also making possible the slowing down of movement at end of stroke.

Blake Pump

Fig. 38 is a diagram of a single cylinder pump, built by the Smart-Turner Co. The main valve is controlled by an auxiliary piston and slides on a movable seat. The movable seat is moved by the main piston rod through crosshead lever and tappet connection.

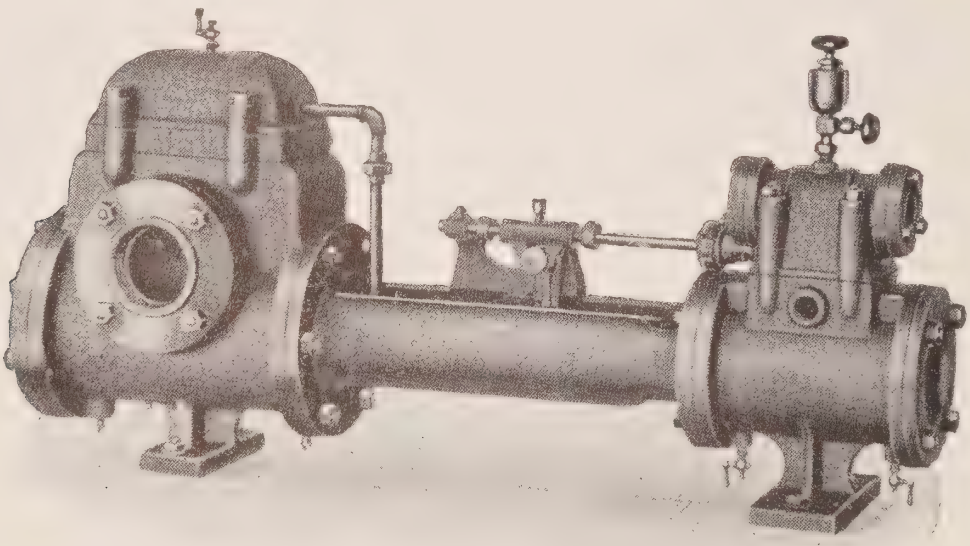


Fig. 38. Another type of single cylinder pump.

When the main piston has about completed its stroke in one direction, the movable seat is moved sufficiently to open a port and allow steam to enter one end of the cylinder of the auxiliary piston, causing this piston to move to a position, carrying with it the main valve, which opens the ports for admission of steam to the opposite end of the main piston, and connecting the other side of the piston to the exhaust port, thus causing the main piston to reverse its stroke.

When the main piston has again reached the end of its stroke, the auxiliary piston and valve are again moved and the main piston starts back again. Fig. 39 is a sectional view of the Blake Pump.

Knowles Pump

Fig. 40 shows a sectional view of the Knowles pump. The valve gear motion differs from the Blake in that, instead of having a movable seat to the main valve which moves

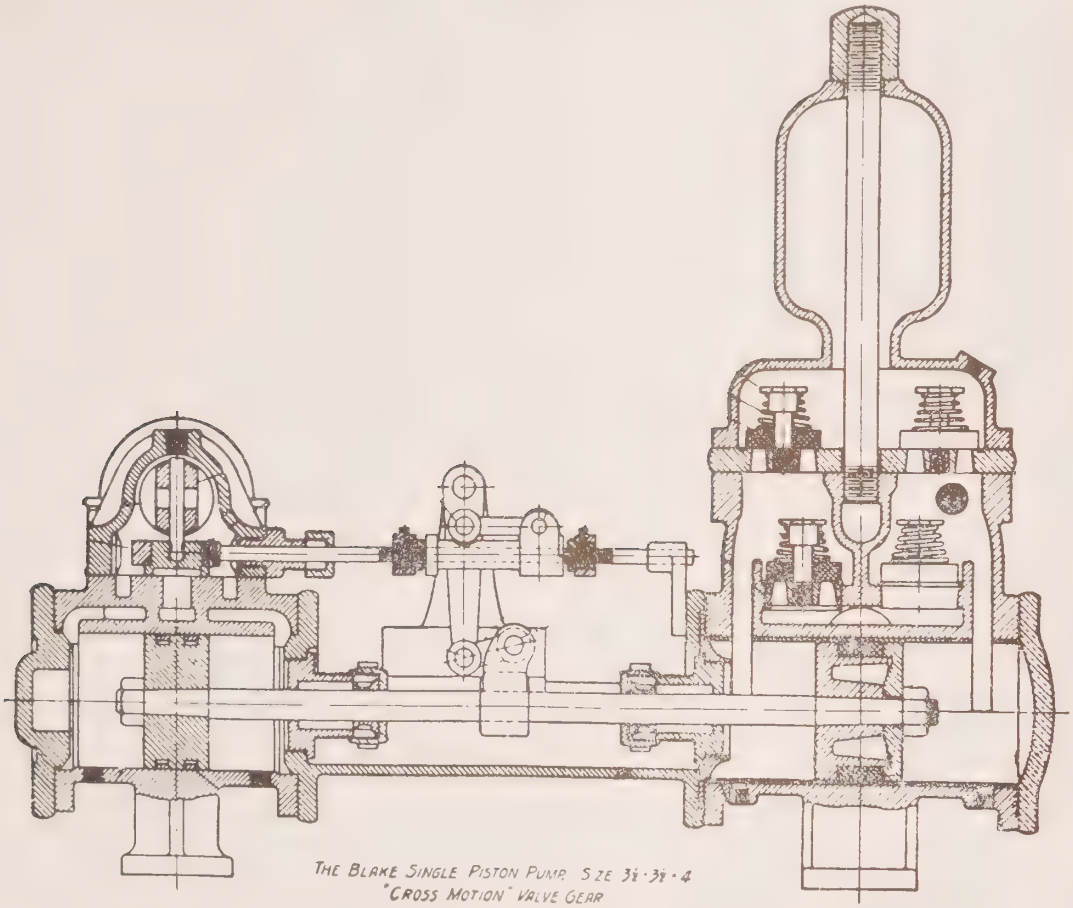


FIG. 39. Sectional view of single cylinder pump.

and opens a port to the auxiliary piston cylinder, the auxiliary piston itself is made to rotate slightly with every stroke of the pump.

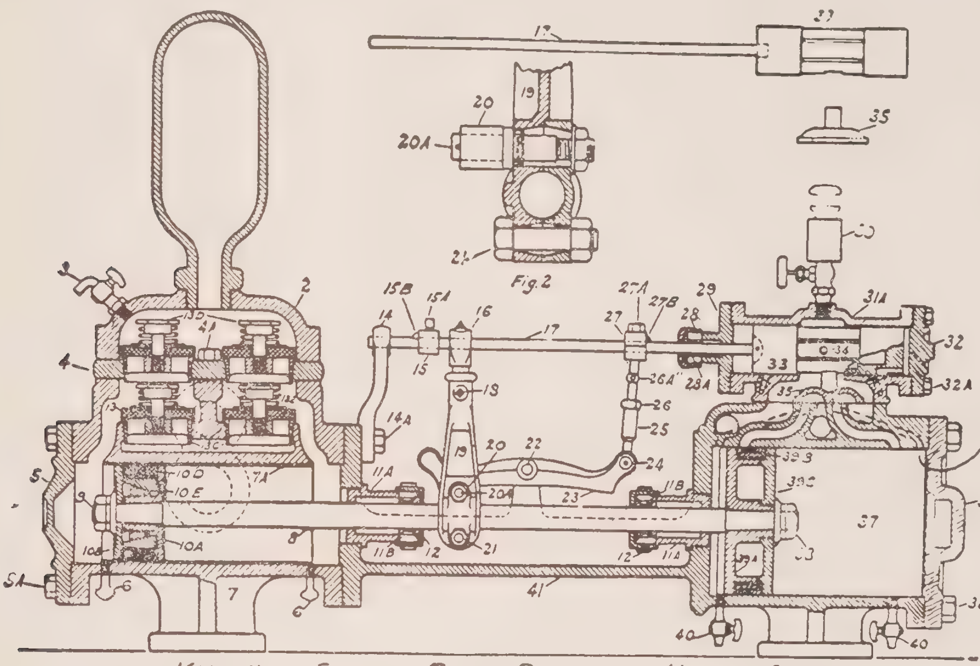
This twist of the piston causes a small port in the auxiliary piston itself to communicate with the steam chest and allows steam to the end of the piston, thereby causing it to move, carrying the main valve with it.

Piston Type Pump

The following illustrations show in section, different forms of water cylinders (all double-acting) commonly used in pump construction.

Fig. 41 is the piston pattern which is undoubtedly the most popular and most widely used type. It is, in the first place, the least expensive form of pump cylinder, takes up the smallest amount of space, and on account of the shorter water passages and smaller clearance spaces, is better adapted for picking up water on high suction lifts without the necessity of priming.

It is also best suited for pumping clean liquids. Any considerable amount of grit in the water causes bad wear in this type of pump, as the grit deposited on the bottom of the cylinder bore, will become imbedded in the piston packing and will scratch the cylinder lining with every stroke of the pump.



KNOWLES SINGLE PUMP-STANDARD VALVE GEAR

FIG. 40.

The cylinder is also called the submerged piston type, as, owing to the position of the suction and discharge valves above, the piston is always under water, which is an advantage in starting up, as the clearance space in the cylinder being filled up, less air has to be displaced and the water to be handled is promptly picked up. It is, of course, necessary to keep the piston properly packed in order to prevent leakage by the piston and to do this the cylinder head and piston follower must be removed, which necessitates shutting down the pump.

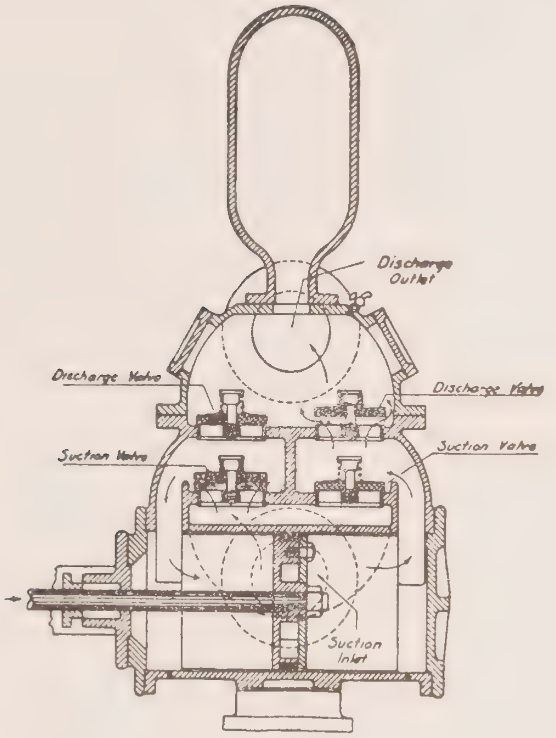
Plunger Type Pump

Fig. 42 shows a water cylinder of the inside plunger type. In this construction the piston becomes a long cylinder which makes its stroke through a short ring bolted to the partition dividing the two ends of the cylinder.

The ring usually has a number of small grooves turned in its circumference, which become filled with water during the movement of the plunger and form a very effective and sufficient packing to prevent leakage, the idea being that the very small amount of water leaking through the sliding fit between plunger and ring takes an appreciable time to fill the little groove before again passing on to the next groove, so that by the time the last groove is reached, the stroke has been completed and the actual leakage, or slip as it is called, is practically nothing.

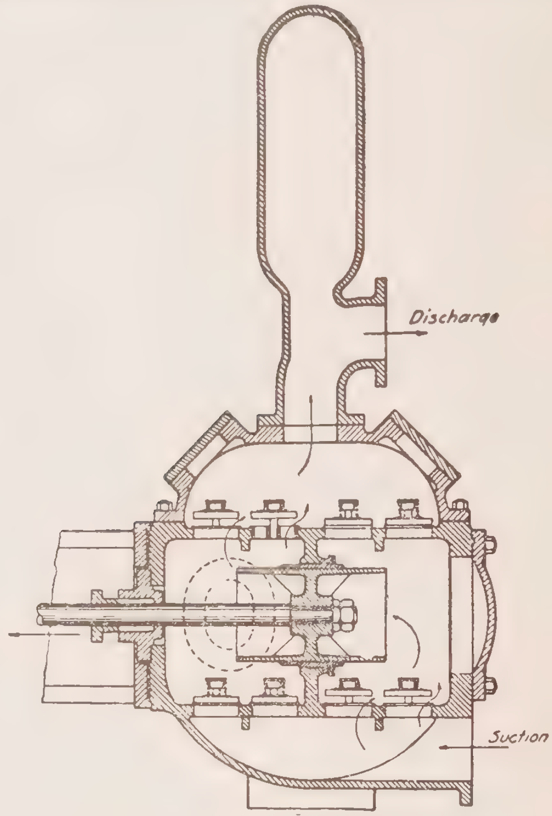
This is the most common form of ring packing and, as will be noted, has no provision for adjustment.

While of course, the ring is bound to wear in time, and without the advantage of adjustment, leakage around the plunger will slowly increase and finally become so great



Packed Piston Pump — Submerged Piston Pattern

Fig. 41.



Inside Plunger Pump - Straight Waterway Pattern

Fig. 42.

that a new ring will be required, which means a considerable replacement expense, yet for ordinary work and with fairly good water the parts will show but little wear for a long period of service, and is to be borne in mind that the amount of leakage or slip is very much less when the pump is running than is the case when the plunger is blocked in one position and the water allowed to force its way steadily through, during a given interval of time.

It is more or less a custom for engineers to figure the amount of their pump slip in this way, but it is quite apparent that the leakage will be a much greater amount than under regular conditions of running, where the plunger is making and reversing its stroke many times in a minute and thus preventing rather than allowing free leakage.

Sometimes the plunger ring is made with a stuffing box attachment so that soft packing can be inserted, and with such construction, the cylinder head of course has to be removed for the adjustment of the packing.

This type of cylinder is better suited for pumping dirty or gritty water than the piston type as shown in Fig. 41, as the sediment will fall to the bottom of the cylinders out of the way of the plunger and moving parts and will not damage them as much as in the case of piston pattern cylinders.

The view shows a water cylinder of the so-called "straight water way" design, which means that the suction valves are below the plunger and the movement of the water from

suction inlet to discharge outlet is substantially in one direction, while in the case of the piston pump cylinder, the water has to pass up through suction valves, then down into the cylinder where it is again pushed up by the piston into the space previously occupied and then on through the discharge valves to the outlet of the pump.

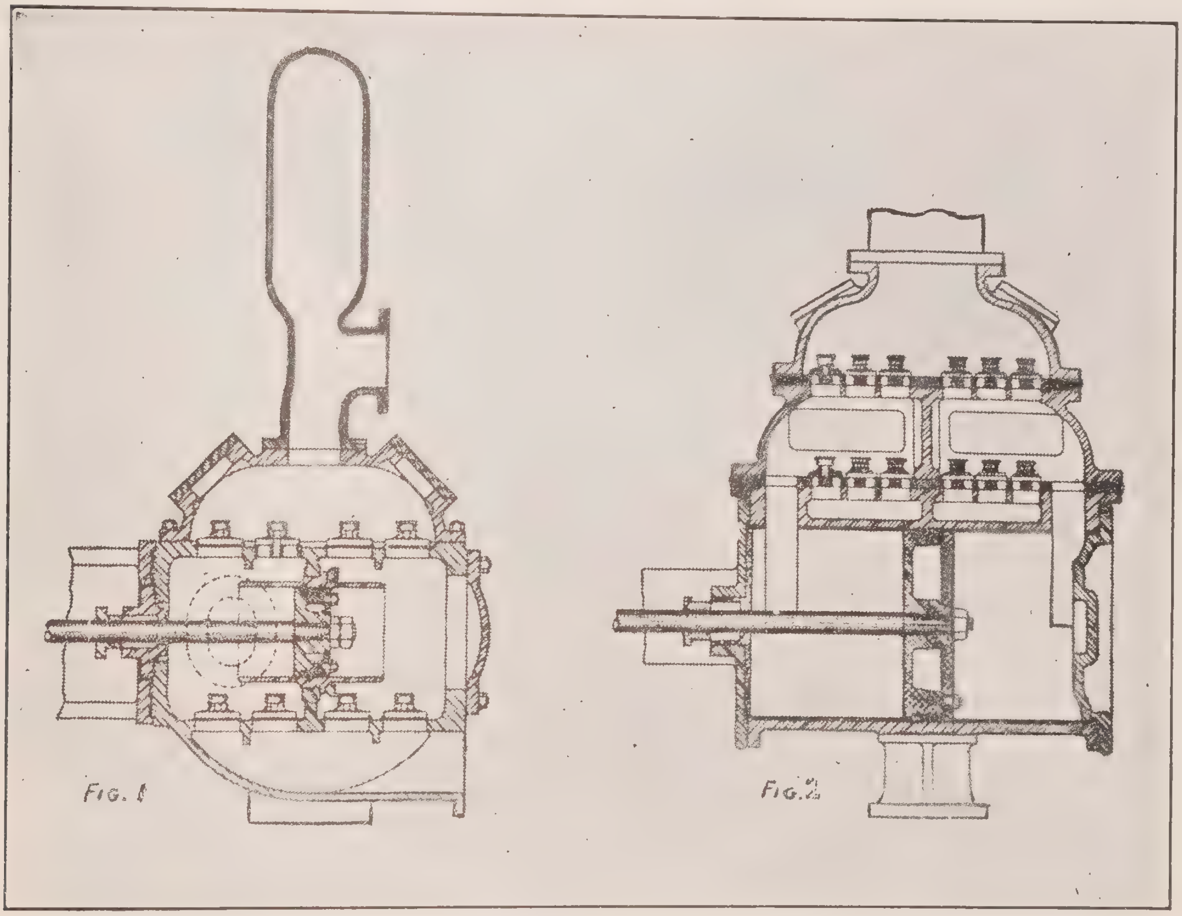


Fig. 43. Straightway plunger pump.

Fig. 44. Sectional view of piston type pump with removable valve casing.

The arrows in Figs. 41 and 42 show the difference in water course in the two types of cylinders. The straight water way is a distinct advantage when large volumes of water are handled, though of course it makes necessary a more bulky cylinder and large clearance spaces that have to be primed before the pump will begin to draft water.

Fig. 43 shows a cylinder of the straight way type fitted with packed piston instead of plunger and ring. This affords the advantages of straight water way and at the same time probably insures a tighter working piston than in the case of a plunger and is preferred for some kinds of service on this account.

Fig. 44 is a sectional view showing a piston pattern cylinder which is called the "double deck" style on account of the fact that the casting is sectionalized and both suction and discharge valve plates or decks are independent pieces bolted in place with a separate chamber between them as shown.

This arrangement is used in cases where the liquid pumped is of a strongly acid nature which would rapidly corrode the metal at such points as where the bronze valve seats are fitted to the iron cylinder, due both to electrolytic action and to the susceptibility of the finished metal surfaces to corrosion, which is greater than the rough tough skin of the iron as cast. The plates are usually made of brass with the valve seats cast in place, but are at times of cast iron with seats driven in. These, of course, will corrode in time, but being comparatively small, simple pieces, can be replaced at a very much less cost than an entire pump cylinder.

Sometimes the plates are omitted altogether and the valve seats are driven into the upper and lower parts of the independent chamber itself, which then becomes the piece subject to renewal.

Fig. 45 shows a water cylinder of the outside centre packed plunger type, which has, besides the advantages of the inside plunger pattern cylinder above, the additional advantage of external packing boxes so that the plunger packing can be adjusted without the necessity of shutting down and opening the pump cylinder.

Any leakage by the plunger is immediately detected and can be quickly stopped by simply setting up the plunger stuffing box follower nuts while the pump is still running. It is also even better adapted for handling gritty water than the inside plunger type, as the grit cannot lodge in any bearing, whereas in the case of the inside plunger cylinder, grit in suspension may get between the plunger and ring and occasion wear.

Still another type of outside packed plunger water end is shown in Fig. 46. This is called the outside end packed plunger pattern and the view shows a cylinder of the pot valve construction, so named from the design of the parts carrying the valves.

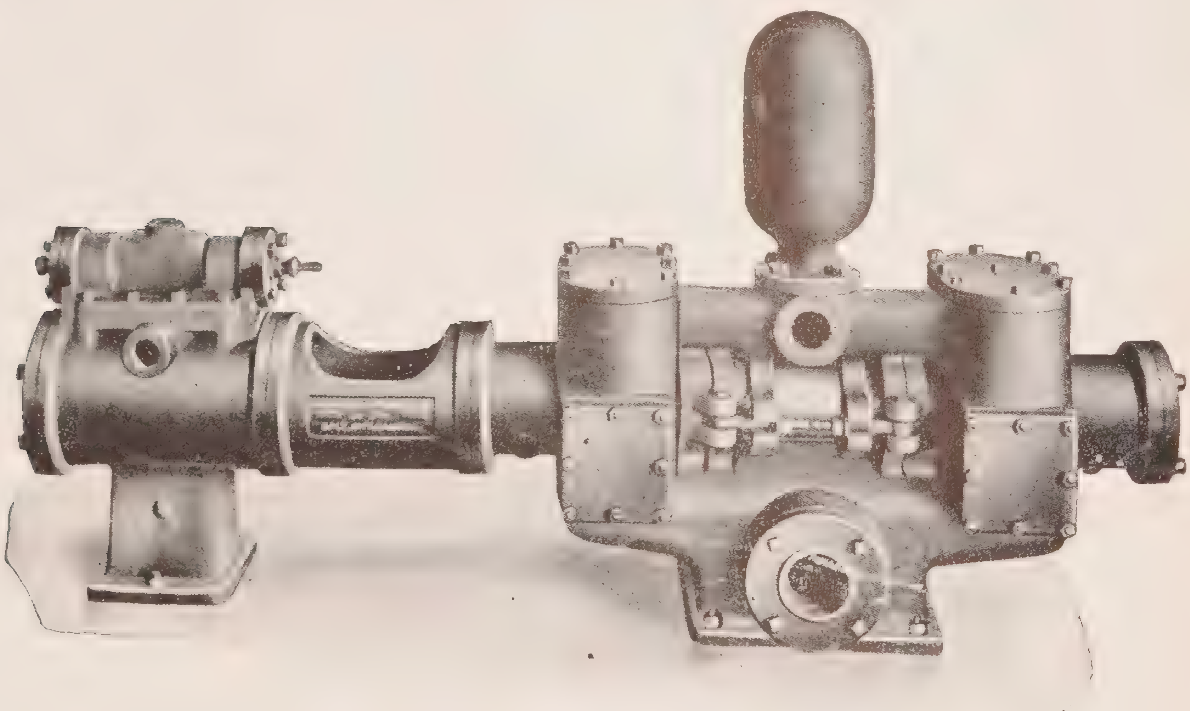


Fig. 45. Outside centre packed plunger type pump.

This type of cylinder affords the advantages of the outside centre packed plunger cylinder just shown and moreover can be used for much heavier pressure work, the construction of all parts, as will be noted, being tubular and very compact so as to properly withstand the strains brought upon them. In this pattern the design makes it necessary to divide the plunger into two parts which work in stuffing boxes at the outer ends of the cylinder and are held together by means of long rods connecting them with the main piston rod. The main disadvantages of this style pump are that a considerable amount of space is necessary for operating room and that the pump is more expansive than any other of the above types.

In the case of an internally packed piston pump there is full discharge pressure on one side of the piston and on the other side a more or less complete vacuum due to the suction lift, while in the case of an externally packed plunger pump with full discharge pressure against the plunger end, pressure on the packing or external side is never less than that of the atmosphere, consequently as the difference in pressures on the two sides of a plunger is less than that of a piston pump, the packing can be less tight and as it is external it can be watched and adjusted so neatly to the requirements that it is easily possible to run the plunger pump with less friction than a pump of the internally packed piston type. That this fact is recognized is shown distinctly in water works practice.

Boiler Feed Pumps

The standard pump for boiler feeding has been the direct-acting steam pump, which is widely used in plants of small or medium size, say below 500 horse-power. Above this, to 1,000 or 1,500 horse-power, it is giving way considerably to the centrifugal type; while in larger plants than these, the centrifugal pump has become practically the standard.

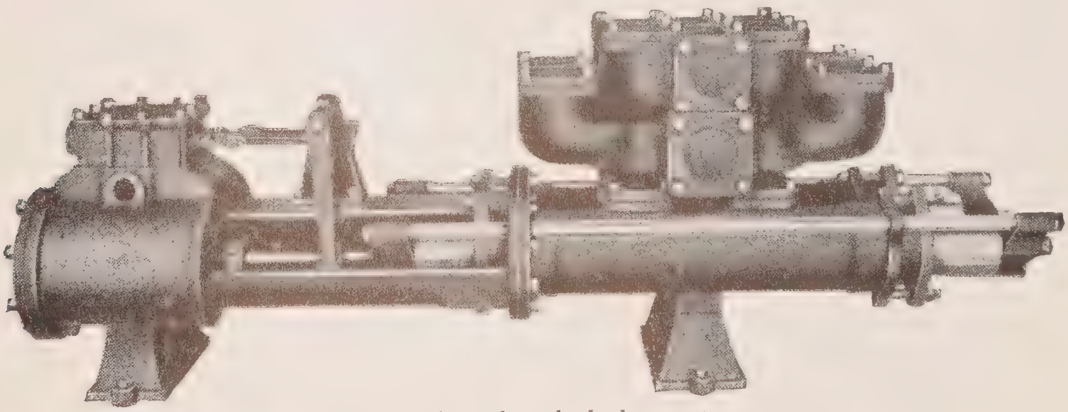


Fig. 46. Outside end packed plunger type pump.

While both the simplex and duplex types of steam pumps are used for boiler feeding, the latter is preferable on account of producing a continuous flow of water.

With regard to piston and plungers in the water end, it is usually found somewhat difficult to keep the piston tightly packed when discharging against pressures exceeding 150 pounds per square inch, and it is common practice to employ through plungers, Fig. 45 and Fig. 46, for 200 pounds and above.

The advantage with the latter type is that the packing is stationary and may be kept in adjustment more easily. For low pressures the piston type is less expansive than the plunger pump.

The advantages of the plunger pump, other than the one already mentioned, are the ease in detecting leaks and repacking, without dismantling the pump.

Among the advantages of the direct-acting steam pump for boiler feeding, are its low first cost, simplicity, low maintenance, and ease of speed regulation to meet changing load requirements on the boilers.

The principal disadvantage is the large steam consumption, which varies from 100 to 200 pounds per indicated horse-power per hour according to size and speed. These figures apply to pumps receiving good care and will be considerably exceeded by those in poor condition.

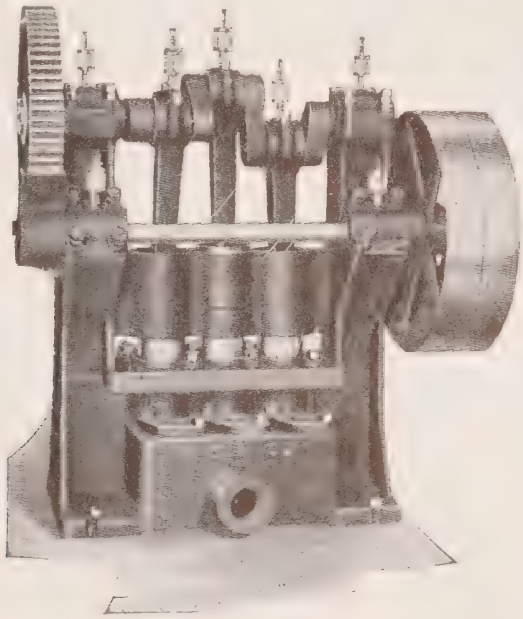


Fig. 47. Crank driven plunger pump.

In general, the number of strokes per minute should be limited to about 50 in the smaller sizes and 40 in the larger. Piston speed is not of so much importance as was formerly supposed, because the maximum strain occurs during reversal of stroke and is not especially affected by the length of stroke or speed of piston, except so far as the momentum is a factor at the time of reversal. The rating of a pump should be in gallons or pounds of water per units of time, under normal working conditions.

While the power pump, Fig. 47, in which the plungers are driven by a crank and connecting rod, is employed for boiler feeding to some extent, its use is limited, because the direct-acting steam and centrifugal types are superior in a majority of cases, when all points are considered. The most common type is that constructed with the cranks set 120 degrees apart, an arrangement that gives a fairly steady flow. Pumps of this type are commonly driven by an electric motor or steam engine, through a belt or silent chain, although geared in some cases. These pumps are commonly used in industrial work as they are more efficient than the direct-acting pump.

Rotary Pumps

Pumps with two parallel geared shafts carrying vanes or impellers which mesh with each other, and other forms of positive driven apparatus, in which the water is pushed at a moderate velocity, instead of being rotated at a high velocity as in centrifugal pumps, are known as rotary pumps. They have an advantage over reciprocating pumps in being valveless, and over centrifugal pumps in working under variable heads. As a rule they are not economical, but when carefully designed, with the impellers of the correct cycloidal shape, like those used in positive rotary blowers, they give a high efficiency.

Fig. 48 shows one type of rotary pump, in which the liquid enters at port I and exhausts at port O.

It will be seen that there are two rotating parts, each mounted on its own shaft and made of such shape that, as they rotate, they always mesh with one another and like a two gear wheel, rotate in opposite directions.

While A is forcing liquid out of port O, B is carrying more liquid, enclosed in space C, towards the outlet O.

Another type of rotary pump is shown in Fig. 49. T is the cylinder of the pump, with suction port R, at discharge port O. Inside the cylinder is a piston A, of small diameter, but set eccentric to the cylinder, to the amount that the piston is in contact with the cylinder at one point. The piston is secured to a shaft which runs central to the cylinder. As the shaft revolves it causes the eccentric rotation of the piston, which sweeps the liquid ahead of it. In contact with the piston is a sliding gate or piston C, which will not allow the liquid past this point and it must port out the outlet O.

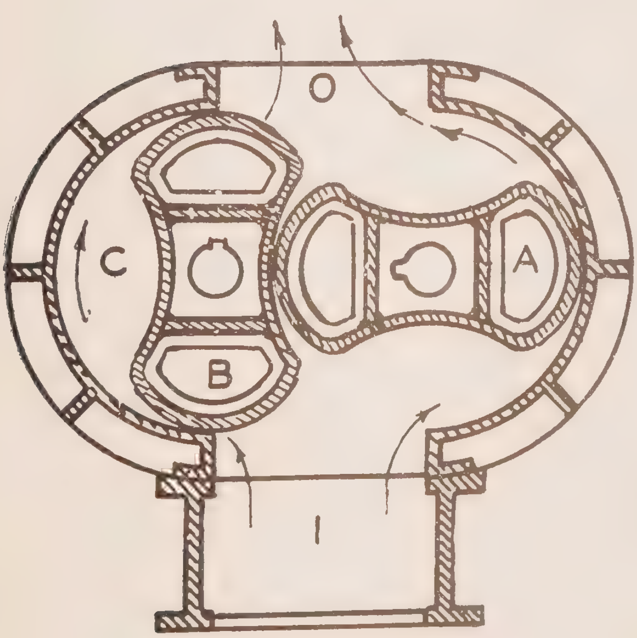


FIG. 48. Rotary Pump.

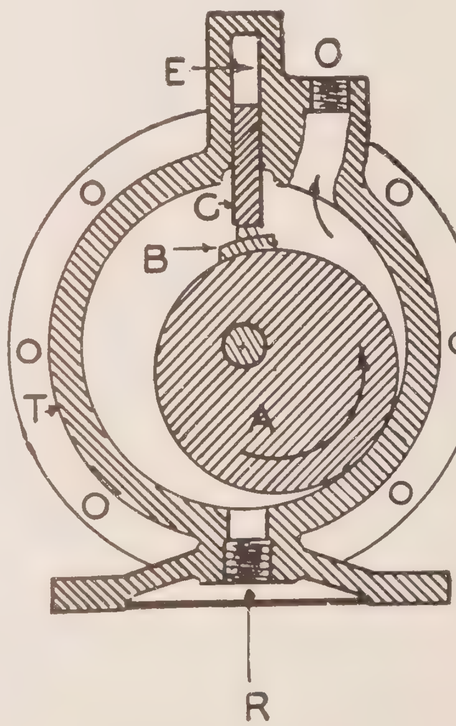


FIG. 49. Rotary Pump.

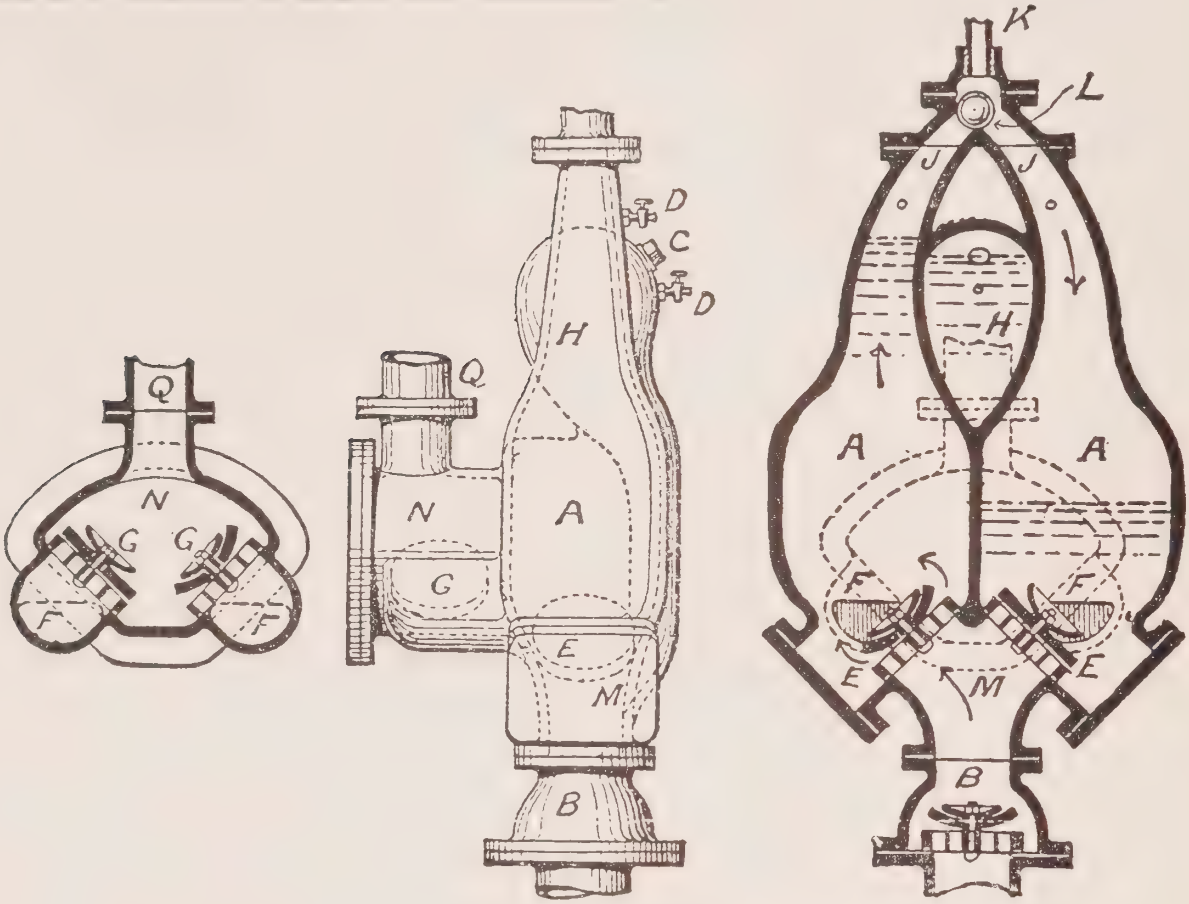


FIG. 50. Pulsometer.

This class of pumps requires strong shafts and extra heavy bearings, owing to the unbalanced thrust caused by the discharge pressure which must all be supported by the shaft.

The Pulsometer

The pulsometer is a form of pump which has no pistons or moving parts, except the suction and discharge valves. Its suction is caused by the condensing of steam within the chamber, and its discharge is caused by the direct pressure of steam upon the water.

Fig. 50 is a diagram of pulsometer. It consists of three chambers, A, A and H. Steam pressure is applied at K. The spherical ball valve L, in the position as shown in the diagram, shuts off the steam from entering the left hand chamber, but allows it to flow into the right-hand chamber A.

If, before turning on the steam, the chambers are all filled with water, through the opening C, which is for that purpose, and held in by foot-valve B, then when the steam is turned on, it will force the water down through a short opening F, past discharge valve G, thence to chamber N, and again through the discharge pipe connection N.

As long as the steam is pressing directly upon the surface of the water in chamber A, there will be little disturbance or mixing of the steam and water, and the water will be

quietly forced out, but when the water has been lowered till the steam reaches the port F, the steam will blow through the port and intermix freely, agitating the water. By intermixing, the steam condenses, causing a partial vacuum to form in chamber A, sufficient to pull the sphere L over, closing the port to the right-hand chamber and allowing it to flow into the left-hand chamber. When the inlet is closed to the steam, a vacuum is formed and the water rushes up through valves B and F, to fill the chamber. By this time the other chamber is empty and the valve J is pulled over, allowing steam to enter first chamber again and repeat the operation.

The chamber H is connected to the suction and acts on the same principle as an air chamber on a pump, causing a more steady flow of water and decreasing shock caused by the inrushing water.

While in operation, pet cocks D are kept open to prevent shock from the rush of suction water and also cause a cushion of air between the steam and water being discharged.

The pulsometer is not an economical pump, but is convenient for handling comparatively small quantities of water such as gather in sumps and sewers under construction. It is cheap, simple and portable, much more easily installed than a reciprocal or centrifugal pump and is better suited to handle dirty water.

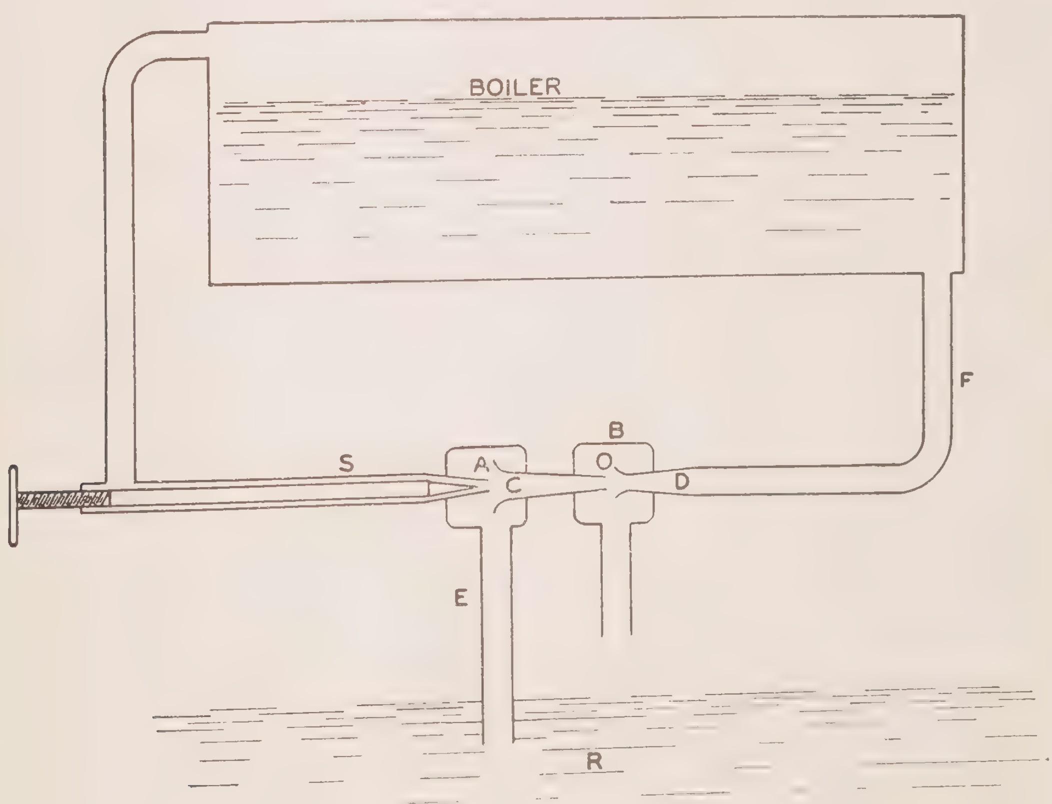


FIG. 51. Skeleton of injector.

The Injector

The injector is an instrument for feeding boilers, and is used instead of, or in conjunction with, a feed pump.

The construction of the injector will be understood by studying the foregoing diagrammatic sketch (Fig. 51). The steam nozzle, S, shows how the steam is supplied to the injector through a small inlet. The amount of the steam-supply is regulated by the coned plug, which fits more or less closely against the orifice.

The combining tube, C, is where the slowly moving water, drawn up from the well R, by the action of the steam-jet, combines with the swiftly flowing stream of condensed steam, and is carried forward by it, into the boiler.

The delivery tube, D, receives the contents of the combining tube. Here, at its narrowest part, the maximum velocity of the jet is attained, and from this point the velocity of the jet is reduced as it proceeds along the diverging tube to the boiler feed-pipe F.

The overflow, O, is an opening or break in the pipe through which excess of water or steam may escape during the operation of starting.

Cause of Failure in Injectors

The Penberthy Injector Company issues the following instructions. If you have trouble look for some of the following causes:

1. Leak in suction pipe (cause of 60 per cent of all trouble).
2. Dirt in the tubes, scale, iron cuttings, or red lead blown in, or drawn in, through steam or suction pipe (25 per cent of all trouble).
3. A loose lining inside a hose (common on traction engines).
4. A leak around stem of suction pipe valve (a common cause).
5. Too low pressure for the lift.
6. Too high pressure on long lifts. Throttle steam to get water.
7. Supply cut-off by strainer getting clogged up.
8. A bad check valve not lifting enough or not at all.
9. Valve in suction pipe not properly regulated below the pressure where it can be thrown wide open.
10. A loose disc on water supply valve.
11. Wet steam, foaming boiler, new boilers, full of grease.
12. Connection to steam pipe used for other purposes and used at same time. This must not be done.
13. Water supply too hot and beyond limit of injector.

To Test for Leaks

When a new injector fails to work, one of the most frequent causes of trouble is a leak in suction pipe. To ascertain if this is the case, fasten down the overflow valve, by placing a piece of wood or cork under the cap. If possible, close the lower end of suction pipe and then turn on steam, which will blow back through suction pipe and appear at the leak, if there be one.

Where an Injector Lifts Water but will not Force to Boiler

This may be due to a leak in water supply pipe, but is more often caused by some obstruction between the injector and the boiler. It often happens that the end of the delivery pipe to boiler becomes choked up with lime sediment; we have seen a ¾-inch pipe reduced in this way to ¼-inch; sometimes the injector is compelled to force through a heater that is old and contains many coils of pipe partially clogged up. If you can, place a steam gauge in delivery pipe to boiler near injector; if it indicates several pounds over boiler pressure when injector breaks, it shows an obstruction. At 50 to 100 pounds pressure, the injector will force against a pressure of 75 to 135 pounds, showing 25 to 35 pounds over pressure; hence it will back pressure equal to this.

Cause of Injector not Showing Full Capacity

1. High pressure, a long lift or hot water.
2. Gravel or dirt getting into chamber where jets meet, thereby clogging up the opening into jet around mouth of same, and in the tapers and spill holes of jet.
3. Gravel or refuse collecting on the strainer. This and No. 2 act exactly the same as if the water supply was throttled.

To Test Capacity

Close globe valve in delivery pipe, take off cap of check valve in same pipe, and take out the check. Place pail under valve, start injector and note time by watch. Allow injector to work exactly one minute. Then measure amount of water delivered and multiply by 60, which will give you capacity per hour.

Fig. 52 shows an injector connected to boiler. A few words of explanation may be added.

Steam Pipe B should always be same size as injector connections, and must be connected to boiler at the highest possible point, and independently of any other pipe, in order to ensure best results, this pipe must be blown out with steam before connecting injector.

Suction Pipe G must always be as large as injector connections, and where lift is over 10 feet, should be one or two sizes larger, reducing to injector size as near injector as possible, and having a globe valve same size as larger pipe. Be sure and put a globe valve (not a straightway) in the water supply pipe.

On a Long Lift a fcot valve should be placed on lower end of suction pipe. Without a foot valve, every time the injector is started, the air must all be exhausted from the suction pipe before the water can reach the injector, and considerable steam is wasted. With a foot valve, the water is held in the pipe when injector is stopped and is there when starting again, so that the saving in steam will soon pay for the cost of this valve.

The Injector will work either from a lift or over-head tank, or from city water pressure. Where the water pressure is heavy, such as is usual where there is a city water works, to facilitate starting on low steam, many persons use two globe valves, H and C, in the water supply pipe, one as near the injector as possible and the other, several feet away, forming a "well" between the two. The far away valve H can then be used to reduce the pressure and the one near the injector for regulating the water supply.

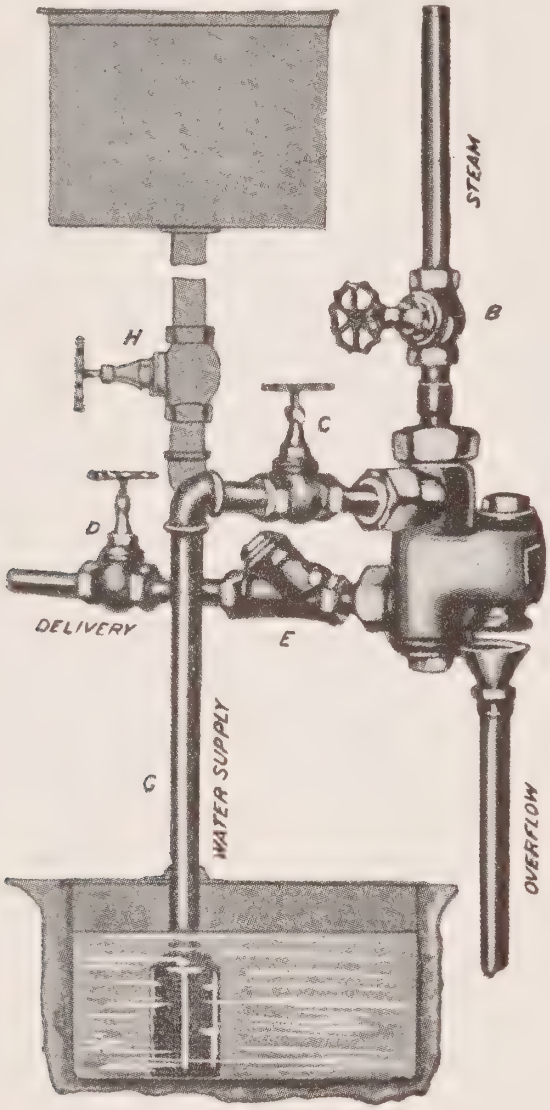


FIG. 52. Diagram showing piping of injector.

The Delivery Pipe should be same size as injector connections, or larger if desired. There should be a check valve, E, and also a stop valve D, in this pipe, the latter for use in case the former gets out of order.

Injector is operated by opening valve B, in the steam supply pipe, full, and then opening the valve C in water supply, with which the amount of water delivered to boiler can be regulated. When this valve has once been regulated properly, the steam valve only will need to be used to start and stop the injector, unless the steam pressure carried has altered to a great extent.

Positive Injector

Its operation is as follows: By-pass and overflow valves are opened and steam is

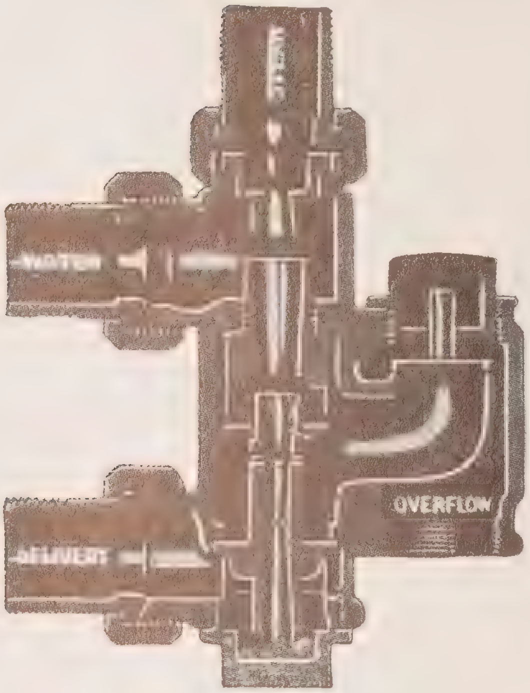


FIG. 53. Sectional view of James Morrison automatic.

admitted, which passes through the tubes and escapes to the atmosphere through the overflow valve. This causes the feed-water to rise until it comes into contact with the jet of steam, which forces it through the overflow. As soon as water appears at the overflow valve, the by-pass valve is closed and the steam control valve is partially opened. The overflow valve is then closed, which forces the water into the boiler.

The positive type of injector will lift water to a greater height and will handle hotter water than the single tube or simple injector. It will also act against greater boiler pressure.

Automatic Injectors

These injectors, which, if stopped for any reason such as the jolting of a locomotive, will automatically start again. This is accomplished by the use of a split nozzle, that is, the combining tube is in two halves, one half being on a hinge, thus forming a flap. When the injector is not working, the loose half hangs open and this allows a large escape of steam through the overflow. When steam is turned on, it flows freely through the injector and removes the entrained air, thus creating a vacuum when the flap closes and forms a combining tube the same as if it were solid.

Exhaust Injectors

This type is very rarely used. It is similar to the ordinary injector, except that the steam nozzle has a very large bore. In this type, the water must flow into the injector. The main thing of interest about this injector is the fact that water can be forced into a high pressure boiler with a steam pressure as low as that of the exhaust from an engine.

Performance of Injectors

Injectors are used to supply boilers with feed-water. They are very easily operated and have some advantages over pumps. They utilize practically all the heat supplied to them in heating the feed-water. They have no moving parts and are cheap in comparison with pumps.

The amount of water an injector will force into a boiler, per pound of steam used, will, of course, vary with conditions, but roughly, an injector will force about 20 pounds of water into the boiler for every pound of steam, when the steam pressure is 60 pounds and the temperature of the water is at 60° F.

A well-known manufacturer gives the following table, relative to the performance of the injector manufactured by him:

Lift in feet	22	22	22	11
Boiler pressure, absolute, lbs.	75.8	54.1	95.5	75.4
Temperature of suction	34.9°	35.4°	47.3°	53.2°
Temperature of delivery	134°	117.4°	173.7°	131.1°
Water fed per lb. of steam, lbs.	11.02	13.67	8.18	13.3

When used for feeding water into a boiler, the injector has a thermal efficiency of 100% less the trifling loss due to radiation, since all the heat rejected passes into the water which is carried into the boiler.

The loss of work in the injector due to friction, reappears as heat which is carried into the boiler, and the heat which is converted into useful work in the injector, appears in the boiler as stored-up energy.

Although the injector thus has a perfect efficiency as a boiler-feeder, it is not the most economical means for feeding a boiler, since it can draw only cold or moderately warm water, while a pump can feed water which has been heated by exhaust steam which would otherwise be wasted.

Why High Temperature Water Cannot be Lifted by Injectors or Pumps

When the steam is first turned on the injector, it passes at a high velocity from the steam tube to the combining tube, between which there is an open space. As the steam passes this intervening space, it entrains a portion of the air from the body of the injector and the suction pipe, and carries the air with it to the atmosphere.

As the air is removed from the pipe and no more can enter, the pressure of air is naturally reduced lower than the atmospheric pressure. The pressure on the water outside of the suction pipe being greater than that in the pipe, causes the water to rise in the pipe until it reaches the steam jet in the injector, when it will combine with the steam and be forced to the boiler. This is what happens if the water is cold, but if the water is hot, the factor of the boiling point of water has to be taken into consideration.

By a study of the steam tables we find that water boils at many different temperatures, depending upon the pressure it is subjected to. For instance, water boils at 212° when

subjected to atmospheric pressure, and at about 100° when subjected to one pound absolute pressure (28 inches of vacuum).

Now suppose the injector was placed 23 feet above the surface of the water of the tank from which it was drawing, before the water can rise to the injector, the pressure in the pipe must be reduced below atmospheric pressure by the pressure of ten pounds, which is required to balance a column of water 23 feet high. Therefore the pressure within the pipe must be reduced to 14.7 — 10 = 4.7 pounds.

From the steam table we find that water boils when subjected to a pressure of 4.7 pounds absolute at a temperature of 150° F., therefore, if the water in the tank has a temperature of over 158 degrees, the water in the pipe will boil and the steam rising will fill the pipe and no water can reach the injector.

It must be remembered that all steam from the steam jet must be condensed in the injector, and therefore, even if the lift be not great, but the temperature of the water high, the great volume of high temperature water required to condense the steam may be beyond the capacity of the injector to handle.

Pumps, for the same reason as with injectors, cannot handle hot water if the suction lift is too great.

REFRIGERATION

REFRIGERATION

To the beginner there is something of mystery about refrigeration and how it is possible to make ice on a summer day. The matter simplifies itself if certain phenomena of nature, which man has been able to use to his advantage, are considered.

These may be listed as:—

(1) A liquid cannot become a gas unless it absorbs heat which does not raise its temperature. For instance, water in a tea kettle will rise in temperature till it reaches 212 degrees, but afterwards does not get any hotter, no matter how great the fire is under it. The only change that takes place is that the water turns to steam.

(2) A gas cannot become a liquid unless it gives off heat which does not lower its temperature. For instance, steam in a radiator may heat a room by turning to water, but the temperature of the water will be just the same as the steam.

(3) A liquid will not convert to a gas as readily when under pressure, but requires a higher temperature than it does if not under pressure. For instance, the water in a tea kettle will start to boil when a temperature of 212 degrees is reached, but the water in a boiler carrying 150 pounds pressure will not boil until a temperature of 366 degrees is reached.

So far we have only discussed water and steam, but the same laws are equally true of ammonia liquid and ammonia gas. The only difference is that ammonia liquid boils at a very much lower temperature than water. For instance, water in the open air will boil at 212 degrees while ammonia liquid will boil in the open air at zero weather and it is equally true that to liquefy ammonia gas under atmospheric pressure, we would require at least 28 below zero weather.

Of course, as we mention in (3), if the pressure is increased on the ammonia gas it will liquefy at a higher temperature. For instance, at 150 pounds pressure the gas will convert to a liquid at a temperature of about 78 degrees.

In the process of refrigeration the ammonia gas is first made to liquefy, then boil, then liquefy, then boil, et cetera, as long as the plant is in operation. Let us bear in mind that when it boils, it must take heat from somewhere and when it liquefies, it must give off heat.

We will follow the course of the ammonia through the refrigerating system. The gas flows to the compressor and is compressed to a pressure of about 150 pounds and forced into the condenser. In the condenser the pressure will, of course, be about 150 pounds. Now, as we said before, when ammonia gas is under a pressure of 150 pounds, it will liquefy at a temperature of 78 degrees, therefore, if water at a temperature of say 70 degrees or less is circulated through pipes in the condenser, the gas will liquefy and will give off its latent heat to the water, and this heat will be carried off to the sewer.

The liquid ammonia in the condenser is then allowed to flow out through a small pipe to the expansion coils. On this pipe is a valve which controls the amount of liquid passing. As soon as the liquid passes this valve the pressure is greatly reduced, with the result that the liquid boils and reverts again to a gas. As we have already stated, the liquid cannot

turn to a gas without absorbing heat. It therefore absorbs heat from the surrounding atmosphere of the room and as the room is robbed of its heat, it naturally becomes colder, or, if the coils are placed in a brine tank, the brine is robbed of its heat. When the ammonia has absorbed sufficient heat to be converted to a gas, it flows back to the compressor and the operation is repeated.

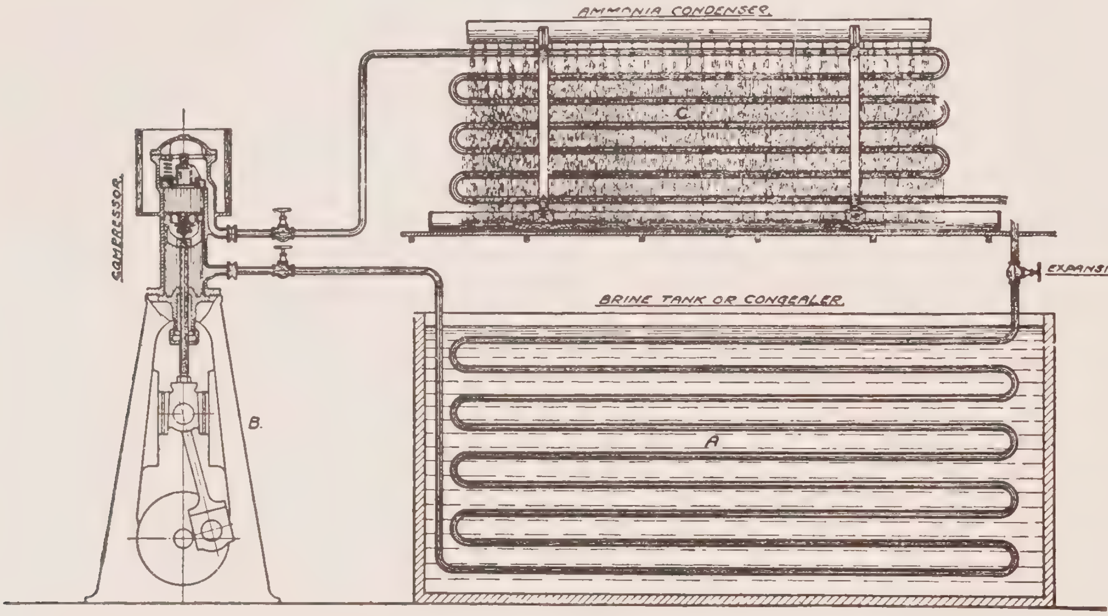


Fig. 55. Simple sketch showing circuit of the ammonia through a refrigerating system.

The simplest form of refrigerating apparatus would consist of three principal parts as shown in Fig. 55.

A is a brine tank, or, as it is sometimes called, the "congealer," in which the ammonia is vaporized and the refrigeration produced. This could have been represented by a refrigerator box, in which case the cooling coils would cool the air in the box instead of the brine in the tank.

B is the ammonia compressor which is a combined suction and pressure pump, pumping the ammonia gas from the cooling coils as fast as it is formed and delivering it into the condenser.

C is an ammonia condenser consisting of a pipe coil into which the ammonia gas is discharged by the compressor at high pressure and changed back to its liquid state by means of cooling water flowing over it.

Referring to Fig. 55, the apparatus is first charged with a sufficient quantity of the cooling medium, which is stored in the lower part of the condenser C. A small cock or expansion valve in the pipe leading to the congealer or brine tank A is opened slightly, allowing the liquid to pass into the evaporator coils. These coils perform the same office as the tubes or flues in a steam boiler, and may, with equal propriety, be named the heating surface.

The amount of water converted into steam in a boiler depends on the number of square feet of heating surface, the temperature of the fire and the resulting pressure which the steam exerts. The same is true of the capacity of the heating or heat-robbing surface of the coils in the evaporator. The heat is transmitted through these coils, being taken from the substance surrounding them and absorbed by the refrigerating medium. This heat causes the refrigerating medium to boil and creates a vapor, just as water when boiling gives off steam.

As previously explained, the surrounding substance parts with an equivalent amount of heat and thus becomes cooler, this heat being transferred to the cooling medium where it is taken up and absorbed in proportion to the pounds of liquid evaporated. The quantity of liquid evaporated is under the control of the expansion valve, which must be regulated to suit the capacity of the compressor under working condition.

As the gas begins to form in the evaporator the compressor pump B is set in motion at such speed as to carry away the gas as fast as it is formed. This is discharged into the condenser under such pressure and temperature as will bring about condensation and restore the gas to its liquid state, ready again to pass through the expansion valve. This constitutes the refrigerating cycle, which is continuous so long as the compressor is kept in operation and the proper quantity of water is circulated over the condenser. The condenser water absorbs the heat of compression and the heat that the refrigerant has absorbed in the evaporator.

Properties of Ammonia

Pure anhydrous ammonia is supplied in strong iron cylinders in liquid form. It is colorless, has a pungent alkaline odor and one cubic foot of the liquid weighs approximately forty pounds.

At ordinary atmospheric temperatures it exerts a pressure of about 150 pounds on the cylinder and if the cylinder is opened and the pressure relieved the liquid ammonia will immediately expand into a gas.

When a liquid passes to a gaseous or vapor state a certain amount of heat is required to bring about the change. As this heat is absorbed during the process of vaporization it is called the latent heat of vaporization, and the science of refrigeration is based on this natural law.

The latent heat of ammonia is about 565 heat units at atmospheric pressure, that is, each pound of liquid ammonia will take up 565 heat units from surrounding objects when it changes into a gas at atmospheric pressure.

The boiling point of water is 212° Fahrenheit at atmospheric pressure. The boiling point of pure liquid ammonia at atmospheric pressure is about 27° Fahrenheit below zero.

If you place an open glass of ammonia liquid in a bank of snow it will absorb enough heat from the snow to boil, while on the other hand a fire will be required to boil the water.

Note: We are speaking of pure ammonia which has been liquefied, and not of aqua ammonia which can be bought at the local drug store and which is ammonia gas that has been absorbed in water.

It is these physical properties of ammonia, namely the fact that it is a liquid at ordinary temperature and about 150 pounds pressure, and that it boils off into a gas at atmospheric pressure and very low temperature, together with the fact that it is readily manufactured and can be procured at a nominal cost, which make it such an ideal refrigerating agent.

Other Gases Used for Refrigerating Purposes

We have so far spoken of ammonia as the only refrigerating agent, but although it is by far the most commonly used, there are a number of other gases also employed.

For instance on board ship and in hospitals, carbon dioxide is commonly used, the main reason being that unlike ammonia it has no smell. Also, it is not dangerous when inhaled and it will not burn. It requires, however, a much higher pressure to liquefy than does ammonia.

There are three other gases in common use in small machines, namely, ethyl chloride, methyl chloride and sulphur dioxide. These gases do not require so high a pressure and so low a temperature to liquefy. In small domestic machines in which these gases are usually used, the cooling is done by a fan blowing air on the condenser instead of the water cooling apparatus necessary in ammonia and carbon dioxide machines.

Pressures and Temperatures at Which Refrigerating Gases Liquefy

A comparison of the pressure required to liquefy different gases when cooled in the condenser to a temperature of 86°, which is about the temperature that could be expected when cooled by water or air of ordinary summer temperature:

	Temperature	Pounds Gauge Pressure
Carbon dioxide	86°	1025
Ammonia	86°	155
Sulphur dioxide	86°	52
Methyl chloride	86°	83
Ethyl chloride	86°	12.5

At the temperature of 86° the heat of evaporization (latent heat) for the above mentioned gases are as follows:

Carbon dioxide	(CO_2)	=	27	B.T.U.
Ammonia	(NH_3)	=	491	"
Sulphur dioxide	(SO_2)	=	143	"
Methyl chloride	(CH_3Cl)	=	158	"
Ethyl chloride	(C_2H_5Cl)	=	162	"

Latent heat is the quantity of heat that one pound of liquid can absorb while converting to a gas.

A B.T.U. (British thermal unit) is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Care of Small Refrigerating Machines

Common difficulties occurring in the operation of refrigerating machines, their causes and remedies, are given in tabular form, and are fully explained in the text following the numbered paragraphs.

Ammonia Compressor Troubles, Their Cause and Correction

Trouble	Cause	Remedy
1. Too high condensing pressure.	Too little or too warm condensing water.	Supply more or cooler water to condenser.
2. Too high condensing pressure.	Condenser coils fouled with scum or scale.	Scrape condenser coil clean.
3. Very high condensing pressure, trembling of the pressure gauge and condenser pipe temperature corresponding to the pressure considerably higher than the condensing water discharge temperature.	The presence of air or non-condensable gases in the system or too great a charge of refrigerant.	Blow-off air or non-condensable gases. Take ammonia out of the system.
4. Too low condensing pressure.	Too small a charge of gas.	Add ammonia to the system.
5. Rapid fall of suction pressure, increase of condenser pressure.	Expansion valve closed or open too little.	Gradually open expansion valve till correct condition is obtained.
6. Too high suction pressure. Discharge connection cold. Heavy frost on compressor.	Expansion valve too wide open.	Gradually close expansion valve till correct condition is obtained.
7. Loud hammering of compressor valve.	Broken spring on compressor valve.	Put in new spring.
8. Irregular action of compressor valves.	Dirty or leaky compressor valves.	Overhaul valves.
9. Capacity of compressor reduced.	Leaky piston.	Overhaul piston and cylinder.
10. Stuffing box and discharge pipe too hot.	Expansion valve closed or open too little.	Open expansion valve wider very slowly.

(1) The correct amount of condensing water is about three gallons per minute, per ton of refrigerating capacity of the machine, with a 9 degree range of temperature of water flowing to and leaving the condenser.

To determine whether the condenser pressure is too high, reference must be made to an ammonia table giving the properties of saturated ammonia gas.

It will be noticed that for every temperature of the gas, there is a corresponding pressure. Assume that the temperature of the condensing water leaving the

condenser is 70 degrees F. The high-pressure gauge should show a pressure corresponding to 8 or 10 degrees higher, or about 80 degrees F., which is 139.40 pounds. If the pressure shown on the gauge is higher than this, the causes given in the table should be investigated.

(2) If a double-pipe condenser is used, examination of the water pipe, which is the inner pipe, should be made to see that it is not clogged with slime or encrusted with scale. The surface of atmospheric condensers should be examined for the same conditions. Double-pipe condensers should be located in as cool a place as possible.

Atmospheric condensers should be placed so that they are protected from the direct rays of the sun and so that they will get the benefit of the prevalent summer winds. The wind will cause some of the condensing water to evaporate and thus cool the rest of the water with a resultant lowering of the condenser pressure.

In some localities the wind is so strong that it will blow the water off the condenser, resulting in increased pressure. To avoid this and to protect the condenser from the direct rays of the sun, a slatted housing is sometimes built over the condenser, which allows the wind to enter but breaks its force.

(3) Before deciding that air or non-condensable gases are present in the system, the operator should be thoroughly satisfied that the excessive pressures are not due to the causes mentioned in (1) and (2) of the table, because too frequent purging is one of the greatest sources of high ammonia consumption and waste.

It is customary to purge by having a valved connection at the top of the condensers from which a connection can be run to a pail of water. As long as bubbles can be seen rising, non-condensable gases are being discharged. When ammonia starts to blow off water absorbs it, the bubbles stop and a crackling sound can be heard. The purging valve should be closed immediately when this occurs.

If there is too much refrigerant in the system, the gauge-glass on the liquid receiver will show too high a level. The correct level when the plant is in operation and doing its greatest amount of refrigeration, should be specified by the manufacturer who installs the machine. Ordinarily, from 25 to 30 pounds of ammonia is required per ton of refrigeration.

To reduce the amount of refrigerant in the system, a connection should be made from the drain pipe on the liquid receiver to an empty ammonia tank and the liquid allowed to drain out until the proper amount is present. Care should be taken not to fill the ammonia shipping tank too full. Do this by weighing it as the liquid receiver is drained.

(4) Reference to the ammonia table and inspection of the gauge-glass on the liquid receiver will determine whether this trouble exists. Ammonia should be added through the charging valve of the system, care being taken not to add too much.

(3) The condition under (5) of the table causes in efficient operation because it results in the gas being superheated instead of saturated. Saturated gas is gas

in contact with its liquid, and its volume per pound for a particular pressure corresponds to that given in the ammonia table for that pressure. Superheated gas is gas not in contact with its liquid and occupies a greater volume per pound than that corresponding to its pressure. For example, we see, by reference to the ammonia table, that at 15.7 lb. pressure a cubic foot of vapor weighs 0.1097 lb., or that a pound of ammonia vapor has a volume of 9,116 cubic feet when saturated. If superheated, it will have a greater volume than this per pound, depending on the amount of superheat. This superheat is due to the difference in temperature between the gas, which is cold, and the rooms through which the suction pipe passes, which are comparatively warm. Because of this difference in temperature, the gas is heated, therefore its volume increases. If liquid were present this heat which leaks in would simply supply the latent heat required to evaporate the liquid instead of heating the gas and thus increasing its volume.

With superheated gas, therefore, the compressor pumps a smaller weight of gas per revolution with resultant falling off in capacity.

Under the usual operating temperatures correct conditions will show frost on the suction line just up to the compressor, indicating the presence of liquid, and the discharge pipe will be fairly hot to the hand.

(6) The conditions under (6) of the table, cause inefficient operation because they result in liquid returning to the compressor. If liquid is coming back it will evaporate on the suction stroke and prevent gas from being drawn into the compressor, reducing its capacity. Also, liquid coming back will cool the stuffing-box, cause the packing to contract, and leakage of gas will occur. Do not tighten up on the stuffing-box, but close the expansion valve somewhat until liquid stops coming back.

Where the load on a refrigerating machine varies frequently, it is difficult to pack a rod tight, because, part of the time, when the load is light, liquid may come back, which causes contraction of the packing and leakage. At other times, when the load is heavy, gas comes back superheated, the packing expands and friction is greatly increased, because an ammonia stuffing-box is comparatively deep. This friction increases the power consumption and will carbonize the packing.

With a varying refrigerating load as described, if a stuffing-box is tightened when liquid is coming back, it should be slacked off when the suction is dry. Close attention to and regulation of the expansion valve will eliminate a large amount of stuffing-box trouble.

The adjustment of a stuffing-box is a matter of experience with the particular installation to be taken care of.

When the expansion valve is too wide open, the compressor shows too much frost and the discharge line is cold to the touch.

(7, 8) To make these repairs to valves, et cetera, it is necessary either to pump out
(& 9) the compressor or to close both the main suction and discharge valves and to allow

the ammonia to escape, either through the valve provided on some compressors, or, through an open joint.

To pump out the compressor, close the main liquid valve and then the suction valve. Run the compressor for a few minutes. Stop it quickly and close the discharge valve tight. The by-pass valve from the discharge line to the suction line should then be opened and closed quickly, or the compressor may again be started with the by-pass open and the suction and discharge valves closed and run a short period until a vacuum is created.

The machine should then be stopped and the by-pass closed immediately. The valve for the purpose of allowing ammonia to escape from the compressor can now be opened, or, if such a valve is not provided, a joint can be slowly loosened, but care should be taken, as a pressure is liable to be built up again in the cylinder. The compressor can now be taken apart for inspection and repairs.

(10) See 5.

Bureau of Standards Tables of Properties of Saturated Ammonia

Temperature Table

Temp. F	PRESSURE		Volume vapour ft.³/lb.	Density vapour ft./ft.³	HEAT CONTENT		Latent heat Btu./lb.
	Absolute lbs./in.	Gauge lbs./in.			Liquid Btu./lb.	Vapour Btu./lb.	
t	p	g.p.	V	1/V	h	H	L
—30	13.90	1.6	18.97	0.05271	10.7	601.4	590.7
—25	15.98	1.3	16.66	0.06003	16.0	603.2	587.2
—20	18.30	3.6	14.68	0.06813	21.4	605.0	583.6
—15	20.88	6.2	12.97	0.07709	26.7	606.7	580.0
—10	23.74	9.0	11.50	0.08695	32.1	608.5	576.4
—5	26.92	12.2	10.23	0.09780	37.5	610.1	572.6
—0	30.42	15.7	9.116	0.1097	42.9	611.8	568.9
+5	34.27	19.6	8.150	0.1227	48.3	613.3	565.0
+10	38.51	23.8	7.304	0.1369	53.8	614.9	561.1
+15	43.14	28.4	6.562	0.1524	59.2	616.3	557.1
+20	48.21	33.5	5.910	0.1692	64.7	617.8	553.1
+25	53.73	39.0	5.334	0.1875	70.2	619.1	548.9
+30	59.74	45.0	4.825	0.2073	75.7	620.5	544.8
+35	66.26	61.6	4.373	0.2287	81.2	621.7	540.5
+40	73.32	58.6	3.971	0.3518	86.8	623.0	536.2
+45	80.96	66.3	3.614	0.2767	92.3	624.1	531.8
+50	89.19	74.5	3.294	0.3036	97.9	625.2	527.3
+55	98.06	83.4	3.008	0.3325	103.5	626.3	522.8
+60	107.6	92.9	2.751	0.3635	109.2	627.3	518.1
+65	117.8	103.1	2.520	0.3968	114.8	628.2	513.4
+70	128.8	114.1	2.312	0.4325	120.5	629.1	508.6
+75	140.5	125.8	2.125	0.4707	126.2	629.9	503.7
+80	153.0	138.3	1.955	0.5115	132.0	630.7	498.7
+85	166.4	151.7	1.801	0.5552	137.8	631.4	493.6
+90	180.6	165.9	1.661	0.6019	143.5	632.0	488.5
+95	195.8	181.1	1.534	0.6517	149.4	632.6	483.2
+100	211.9	197.2	1.419	0.7048	155.2	633.0	477.8
+105	228.9	214.2	1.313	0.7615	161.1	633.4	472.3
+110	247.0	232.3	1.217	0.8219	167.0	633.7	466.7
+115	266.2	251.5	1.128	0.8862	173.0	633.9	460.9
+120	286.4	271.7	1.047	0.9549	179.0	634.0	455.0
+125	307.8	293.1	0.973	1.028	185.1	634.0	448.9

INSTRUCTIONS FOR OPERATING SMALL AMMONIA MACHINES

Different types of refrigerating machines have different characteristics, but the following instructions will in a general way, fit into the operation of all machines.

To Start Machine

Never close discharge valve.

Before starting machine, make *sure* to open supply valve to ammonia condenser and machine water jackets. Water valve controls the pressure shown on high pressure ammonia gauge. Gauge should read between 125 and 150 pounds, while machine is in operation. If below 125 pounds, shut off a little water. If above 150 pounds, turn on a little more water. By regulating water valve as stated, proper pressure can be obtained.

After water has been turned on condenser, start machine and open valve called suction valve, as soon as possible.

After suction valve has been opened, low pressure gauge will start to go back towards 0 pounds. When it reaches about 15 pounds on gauge, open up expansion valve. Care must be take not to open this valve *too much*, as it would cause machine to frost. Valve should be regulated so that frost just reaches machine. If machine should become frosted, shut off expansion valve a little, and in a short time, frost will disappear.

After machine has been operating for a short time, if necessary, regulate expansion valve so as to bring frost up to scale trap at machine.

Don't frost up machine.

Don't try to hold any given pressure on suction gauge—this will vary according to temperature of brine or room, if frost is carried just up to machine.

To Shut Down Machine

Close expansion valve.
After closing expansion valve, close suction valve.
After closing suction valve, machine should be shut down *as soon* as possible.
Shut down machine. Close water valve.

If condensers are placed in room which may be colder than freezing, during the winter, care must be taken to see that all water lines on condenser and machine water jackets, are drained out after every operation, as there is *danger* of same freezing and bursting pipe. A necessary drain is provided for machine water jacket and condenser.

Instructions for Charging Oil

Shut suction valve, start machine running until a vacuum is created in crank case, which will happen after machine has made a few revolutions, then place end of hose attached to oil connection on machine in pail of oil, then open oil valve. Do not allow end of hose out of oil, but shut off oil valve before pail is empty, so as to make sure not to suck in any air. Fill oil chamber to height marked on small brass plate near glass. Be sure oil is *perfectly clean* and contains no grit, before placing in crank case.

To Pack Stuffing Box on Machine

Shut off suction valve. Allow machine to run a few revolutions, then shut down machine and shut off discharge valve. After this has been done, open up oil valve where hose is attached and if you find vacuum it is safe to take off stuffing gland. Take out old packing and replace with new. Always *make sure to open* up discharge valve *before starting machine.* Never tighten packing while machine is running more than just enough to avoid ammonia smell.

Charging System with Ammonia

Referring to Fig. 56 to charge the system.

It is always well to place the charging drum on a set of scales, with the back end raised on a block and weighed.

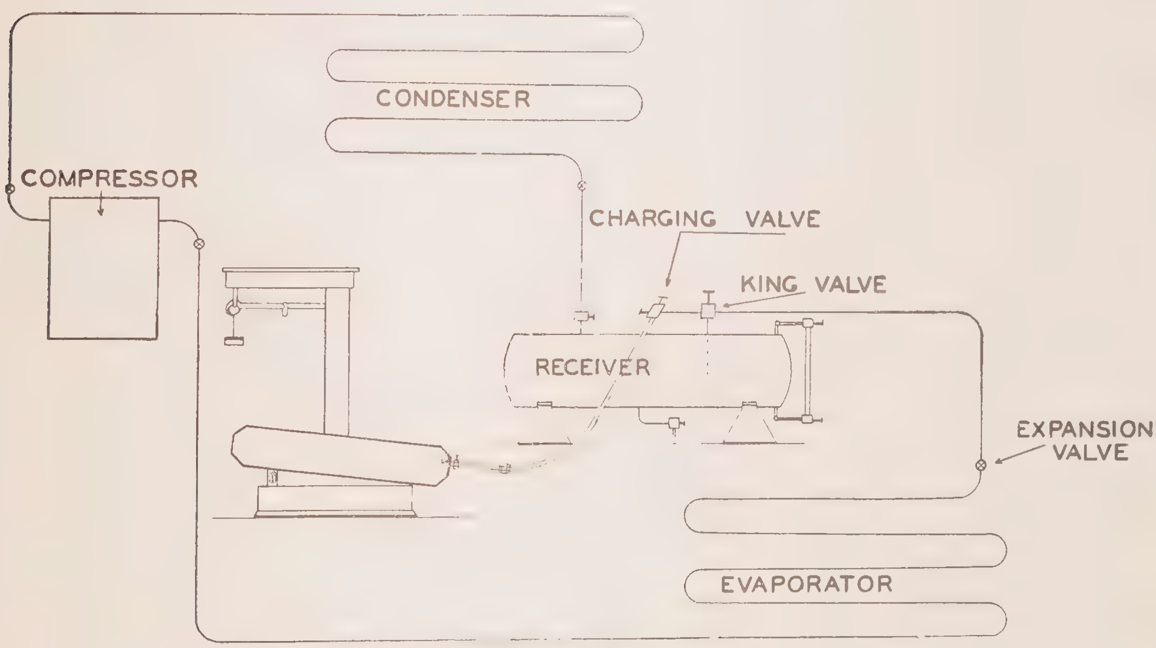


Fig. 56. Diagram showing method of charging system with ammonia.

Be sure the bent pipe inside the cylinder is facing down. This will usually be the case if the valve opening is facing up.

Now connect the drum to the charging valve of the machine with a suitable bent pipe.

While the machine is running and condenser water flowing, close the king valve and reduce the pressure in the evaporating coils to zero or slightly below. Then open the charging valve and also open the valve on end of charging cylinder very slowly and make sure there are no leaks.

It is well to note that the packing gland of this valve has a left hand thread and must be turned in the opposite direction to the ordinary valve to tighten.

If it is not desirable to put the full quantity of ammonia in the cylinder into the system, the scales should be set at the weight required and the valve closed when the scales balance.

If the drum is to be completely emptied the scales may be dispensed with and pumping continued until frost appears on the bottom of the cylinder and up the pipe to the charging valve.

Having completed the charging, close the valve on the cylinder and then the charging valve, and open the king valve. The drum may now be disconnected. Care should be taken, however, as a pressure may build up in the pipe.

Ordinarily, from 25 to 30 pounds of liquid ammonia are required per ton of refrigeration.

Testing for Ammonia Leaks

There may at times be a leak, due to pitting or other causes, of the gas to the cooling water of a condenser, which may go on for an indefinite time undetected. It is well to test for such a leak and this can be done by holding a piece of red litmus paper in the water as it leaves the condenser. If ammonia is present it will turn the litmus paper blue.

Test leaks in joints, soap is sometimes used. If the joint is painted with soapsuds the ammonia gas will blow bubbles. Another and more satisfactory method is to burn a sulphur stick and hold it close to a suspected leak. If dense fumes are formed it is a sure sign that ammonia is leaking.

Pumping Out Condenser

If for any reason, such as to repair a leak, it is found necessary to empty the condenser of ammonia, it may be accomplished as follows:

While the machine is shut down, close the valve between the condenser and the receiver; close the suction and discharge valves; open the cross-over by-pass valves.

Now start up machine and owing to the by-passes, the direction of flow of ammonia gas will be reversed and will therefore be drawn from the condenser and forced into the evaporating coils. This process would be continued until a vacuum shows on the condenser gauge. Then shut down, but, if pressure again shows on the gauge, start machine and run until sure that all gas has been removed.

While pumping out the condenser, care should be taken that the cooling water be turned on full or completely shut off and condenser drained, for, owing to reversing the system, the condenser becomes the evaporating coils and the ammonia liquid in evaporating would cause the water to freeze.

Also, care should be taken that the oil trap on the discharge pipe is drained, otherwise the oil may be drawn back into the compressor.

Also, since the evaporating coils under this reversed condition now becomes a condenser and as there is no cooling water, care must be taken that a high pressure is not allowed to build up in these coils. Furthermore, if the evaporating coils should be coated with ice, the heat from the ammonia will loosen this ice from the pipes and as it drops off in pieces may damage any goods in the vicinity.

By the way, this is a method of de-frosting the evaporating pipes when the ice becomes so thick that it interferes with the free transfer of heat from the room to the coils.

Danger Connected with the Operation of Refrigerating Machinery

As a rule, an industry in which chemicals and highly-compressed gases are used in connection with tanks, pipes and moving machinery, is quite likely to involve a considerable accident hazard and mechanical refrigeration is by no means an exception to this. Safety in connection with mechanical refrigeration may be divided into two phases: (1) safety in operation and (2) safety in case of accident to the apparatus or in case of fire.

Provision of safety-valves on certain parts of the apparatus operating under high pressure, and also some provision for getting rid of all the ammonia in the apparatus in case any break occurs in the circulating system, or in case of fire, should be made.

When a refrigerating system is first installed, it is customary to test it out with air pressure before it is charged with ammonia.

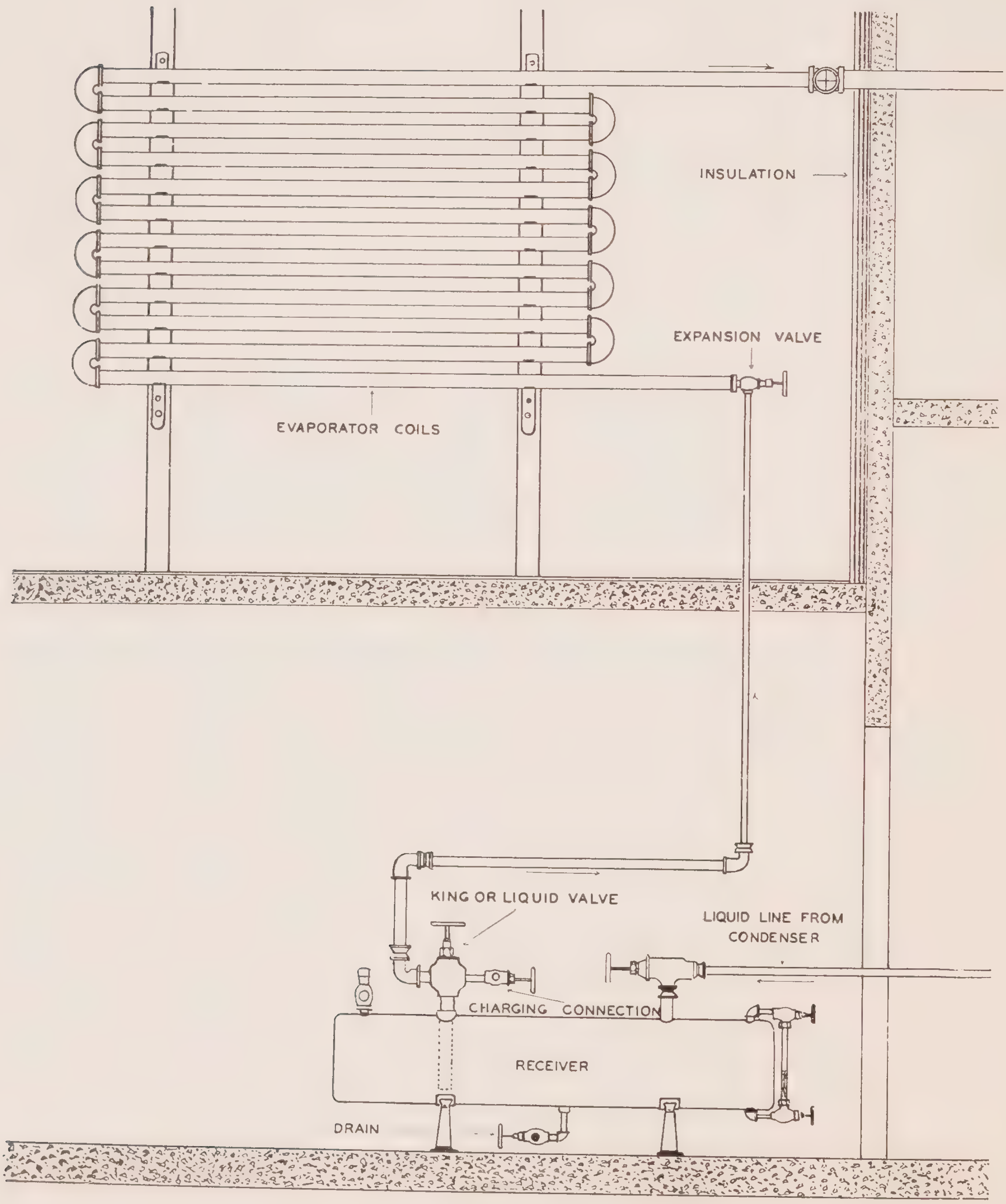
This practice is commendable if properly done, but it may result disastrously if done in a careless way. Explosions sometimes occur during such tests, and these are commonly attributed to the ignition of the lubricating oil used in the compressor. Never allow the compressor to get too highly heated during such a test, and do not use an excessive amount of oil. Keep away from the apparatus as much as possible, because an unforeseen weakness or imperfect joint may cause a failure of some part. Remember that it has not yet been shown that such weaknesses or imperfections do not exist. The test is being made for the purpose of settling this question.

Leaks in any part of the ammonia system often lead to serious results, because a mixture of air, ammonia, hydrogen, oil vapor and other volatile impurities may ignite and cause a violent explosion.

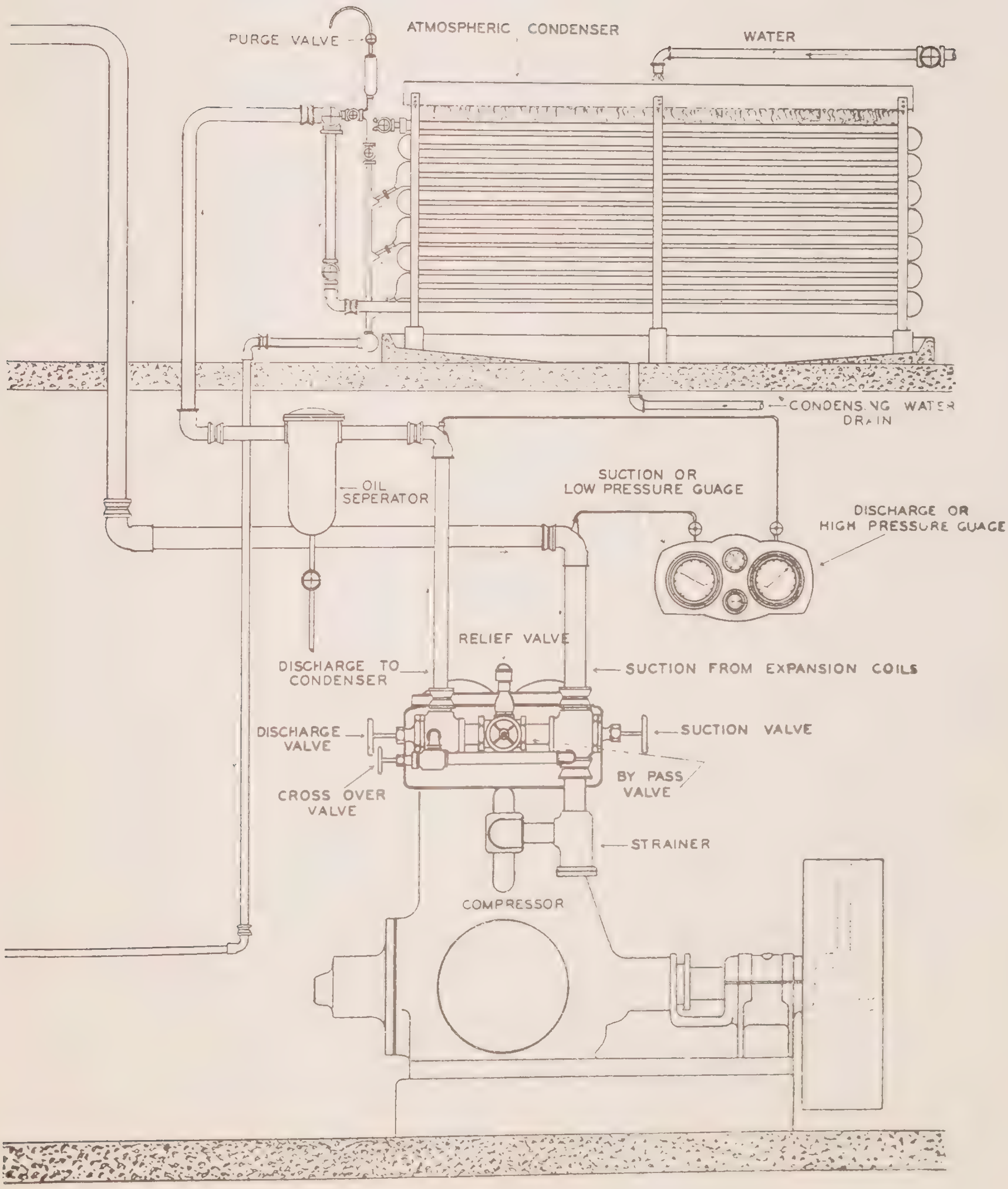
There is no danger of such mixtures exploding, however, unless heat is applied, or they are brought in contact with a flame or spark.

All arc lights and other open flames should be eliminated in rooms where the apparatus is installed, and self-closing doors should be provided, separating other parts of the building from the rooms where leaks are likely to occur. It is also imperative to provide some means of ventilating rooms in which leaks may occur and the ventilating equipment should be so arranged that it can be operated from outside the room.

The greatest danger associated with the use of ammonia consists in the harmful effect of the gas on persons breathing it.



Diagrammatical sketch of a refrigerating



plant showing its component parts.

Special ammonia gas masks are available, but they are not highly efficient when the gas is concentrated and for that reason, oxygen helmets are the only safe and practical respiratory apparatus that can be used by persons who have to enter a room filled with strong ammonia gas. Oxygen respirators should be provided in all refrigerator rooms, and at least one such apparatus should be kept in some place outside the room, where it will be available for use in case it becomes impossible to enter the room and obtain the respirator there.

In operating the expansion valves on compression or absorption systems, the engineers should be careful not to allow too much liquid in the coils at one time.

Considerable experience is required in operating these feed valves. In compression systems the outlets of the coils should be watched constantly to see that liquid is not allowed to pass over and into the compressors. If an appreciable amount of liquid gets into the compressor cylinders, it is likely to do considerable damage by cracking the cylinder head, or bending the piston rod. Liquid ammonia is incompressible and acts in much the same way as water in the cylinder of a steam engine.

Carelessness in charging the ammonia system often results in serious consequences. The charging should be done only through proper pipe connections located near the expansion valve and on the low pressure side of it.

In apparatus in which the charging cylinder is attached to the liquid line, if the main (or "king") valve on the liquid line is not closed when the charging cylinder is attached, the pressure on the line may be greater than that in the cylinder, and consequently, ammonia from the system would flow into the cylinder, filling it completely.

If such a cylinder were heated, even slightly, after the stop-valve were closed, the pressure in it would rise very rapidly and the cylinder itself would be likely to burst. To be sure that liquid has not passed into the charging cylinder, every such cylinder should be weighed before and after charging has been done. The difference in weight will indicate the amount of ammonia that has been put into the system. The charging cylinders should be detached from the system as soon as the charging operation is completed and all cylinders should be stored in a cool place.

Many of the valves on the various pipe lines and tanks are seldom used, but they should be regularly inspected and tested to make sure they are in working order.

An accumulation of rust in the stuffing boxes or on the threads might easily make it impossible to operate the valves, and this would be highly important if an emergency should arise.

The design of the valves used on refrigerating apparatus is particularly important and it must be remembered that special valves are absolutely necessary for the safe operation of the systems. Valve accidents are not uncommon and it is evident that care in the selection of materials, together with careful attention to the installation and upkeep, are essential in reducing these accidents to a minimum.

The installation of safety-valves to prevent excess pressure, is highly important on those parts of the refrigerating equipment that are operated under high pressure. The ammonia escaping from these safety-valves may be discharged through proper pipe connections into the low-pressure side of the apparatus, or, the gas may be conducted away from the refrigerating machine and discharged into the air, or into a tank of water.

When discharging into the air, the ammonia should be conducted by continuous piping to a point above the roof of any building within 50 feet of the valve and then discharged through a diffusing device, designed to thoroughly mix the gas with the air. If the ammonia is discharged into a tank of water, the capacity of such tank should be great enough to provide at least one gallon of water for every pound of ammonia contained in the equipment and this amount of water should be automatically maintained within the tank.

It is evident, therefore, that the use of water for collecting the escaping gas would be practicable only for systems containing up to a thousand pounds of refrigerant. When water is used some provision should be made for keeping it at a temperature above 32 degrees Fahr., to prevent freezing.

Every refrigerating installation containing more than one thousand pounds of ammonia should be equipped with some means of safely drawing off all the ammonia in the system, in case of fire or other emergency.

This may be done by installing an emergency relief line from the low-pressure side of the apparatus. This line should be operated by a hand relief-valve and the ammonia passed by this valve should be conducted to a suitable mixer which will thoroughly mix the escaping gas with water and discharge it into the sewer or an outside body of water. This emergency pipe line should be equipped with a suitable check valve to prevent the water from working back into the refrigerating system.

The question of safety to the workmen is largely in the hands of the workmen themselves, just as it is in almost any industrial plant. For this reason it is important to have the work done by experienced and competent persons and under the direct supervision of one who is thoroughly versed in the operation and upkeep of refrigerating apparatus and who thoroughly understands the dangers that are associated with such machinery.

It is also important to have several of the employees learn approved methods of reviving persons who may be overcome by ammonia gas. The prompt application of artificial respiration, for example, may often-times be the only means of saving a life. In addition to giving prompt and efficient first-aid treatment, the services of a skilled physician should be secured as soon as possible.

Tons of Refrigeration

The usual method of rating a refrigerating machine as to the work it will do, is to state that it is of a certain tonnage, that is, one machine may be rated as a ten ton machine and another a twenty ton machine.

The term "ton" in these cases means the heat required to melt one ton of pure ice at a temperature of 32 degrees, to water at 32 degrees, or it might be expressed as the amount of heat that must be extracted to freeze pure water at 32 degrees.

The commercial "ton" refrigerator is a machine capable of extracting the heat required to freeze one ton of pure ice in 24 hours.

The latent heat of ice is 144 B.T.U., therefore, 144 B.T.U. must be extracted from each pound of water to transform it to ice, or:

144 × 2000 — 288,000 B.T.U. from each ton.

Of course, an ice making machine cannot produce one ton of ice by expending the energy equivalent to 288,000 B.T.U., but will produce somewhere about six-tenths of a ton. The reasons why such is not the case, are:

(1) That there are certain unavoidable losses, such as radiation from pipes and other vessels.

(2) Water is not supplied to the machine at 32 degrees, but will probably be around 60 degrees, therefore every pound of water must be cooled from 60 to 32, which is a loss of about 28 B.T.U. per pound, or 56,000 per ton. Again, the brine must have a lower temperature than 32 degrees.

Horse-Power Required per Ton of Refrigeration for Commercial Operation

H.P.	Tons of Refrigeration	H.P.	Tons of Refrigeration
3	1.05	50	31.2
5	2.1	100	67.2
10	4.7	150	99.2
15	8.9	250	161.1
25	15.6	300	210.3

STEAM PLANT ACCESSORIES

Steam Traps

Steam in pipe lines will contain a certain amount of moisture. This moisture is present for two reasons, firstly, due to priming of the boiler, and secondly, due to condensation of a certain part of the steam by coming in contact with the cool surface of the pipe. The amount of moisture will vary greatly owing to different conditions. It will be comparatively small in high pressure steam lines where there is a rapid flow of steam and the pipes are well insulated with suitable pipe covering, while the greatest amount of moisture will be found in heating systems where an effort is made to condense all the steam in radiators. In the first instance moisture is very objectionable as it is liable to cause water hammer, and if it reaches the engine, retards the working of the piston and is liable to knock the piston head out. In the second case unless the water is removed the pipes will become filled with water and retard the flow of steam. Superheated steam will contain no moisture but the pipe lines should be drained as water is liable to collect in them when the steam is shut off, particularly if the valves are not absolutely tight.

It will be seen that in all cases it is necessary to remove the water. This may be done by the simple method of placing drain on the bottom of the pipe lines, opening them by hand and allowing the hot water to run out and go to waste. This is a very extravagant method as hot water contains much heat.

To remove the condensate and return it to a heater or the boiler where it can be used over again without releasing the steam, the steam trap has been invented. There are a great number of different designs on the market.

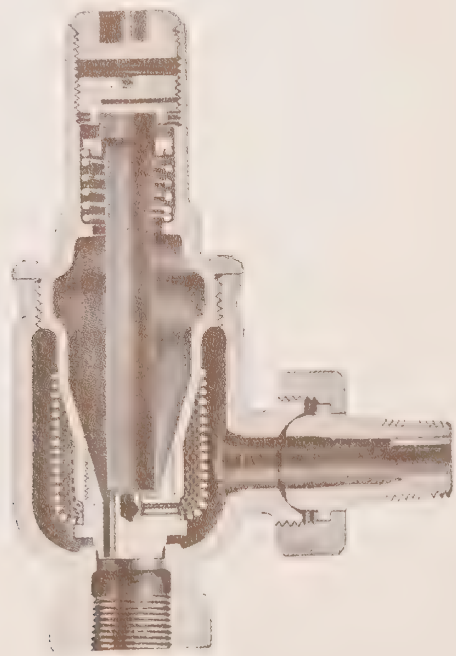


Fig. 1. Webster Thermostatic Trap.

Thermostatic Trap

Fig. 1 is a sectional view of the Webster Thermostatic valve.

The Webster thermostatic valve is used principally on small units of radiation, is adjustable and automatic, permitting water and air to pass but expanding when the plug is surrounded by steam, causing it to seat and preventing waste of steam to the return. This valve is intended for fairly constant low pressure.

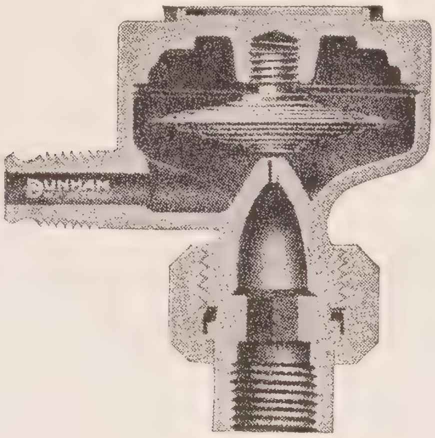


FIG. 2. Dunham Thermostatic Trap.

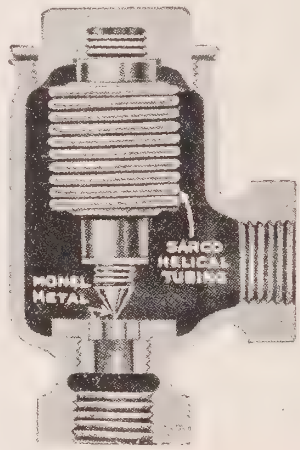


FIG. 2-A. Sarco Thermostatic Trap

Fig. 2 shows a sectional view of the Dunham trap used on radiators.

The disc for all Dunham traps is constructed of two corrugated members made of special composition phosphor bronze, formed under pressure. The curves of the corrugation are designed to distribute uniformly the motion incidental to the disc operation. The disc contains a volatile fluid compounded to respond to a wide range of temperature. This fluid is hermetically sealed within the disc. The disc is permanently adjusted in the cover at the factory and its setting should not be changed.

When it is installed the disc is subject to the same conditions of pressure and temperature that exist within the radiator, and its operation is controlled by these conditions.

As steam enters a cold radiator it forces the cool air which is in the radiator, out through the trap into the return piping. In warming the radiator the steam gives off heat and in doing so condenses to water. The water which is heavier than steam falls to the bottom of the radiator and flows to the trap through which it also passes into the return piping. After forcing out the air, the steam fills the radiator and follows the water to the trap, which, in the presence of steam, automatically closes because the steam is hotter than either the air or water. The heat of the steam vaporizes the fluid within the disc and creates a gas which expands the disc, closing and holding the valve against its seat with a positive pressure, thus trapping the steam within the radiator.

The radiator now thoroughly filled with steam gives off heat, condensing the steam at a uniform rate, and the water of condensation which is cooler than the steam, flows in a steady stream to the trap which it slightly chills, causing it to open, allowing the water to pass out.

The trap adjusts itself to a position corresponding to the water temperature, just as a thermometer does to the room temperature, and permits a continuous flow of water from the radiator.

The operation of a trap attached to a radiator has been described. The traps operate in a similar manner to trap steam when used on any other form of heating surface or to drip piping. The air and water, which are both cooler than steam, cause the trap to open and steam causes it to close. The operation of the trap is not that of alternately opening and closing; it adjusts itself slowly like a thermometer to the temperature conditions present and permits a continuous flow of air and water at a rate to keep the heating surface free from air and water and full of steam, without waste of steam.

Fig. 2-A shows another type of thermostatic steam trap, known as the Sarco.

Bucket and Float Traps

To handle a large volume of condensation the float trap or bucket trap is usually used. The principle involved in both types is practically the same. In the float trap the hollow ball floats on the return condensate water which flows by gravity from the drains on the steam lines to the body of the trap. This float being attached to a suitable lever mechanism, operates a valve on the outlet of the trap. As the water level rises the float rises, opening the valve allowing the water to be discharged and when the level of the water drops, the float is lowered and closes the valve.

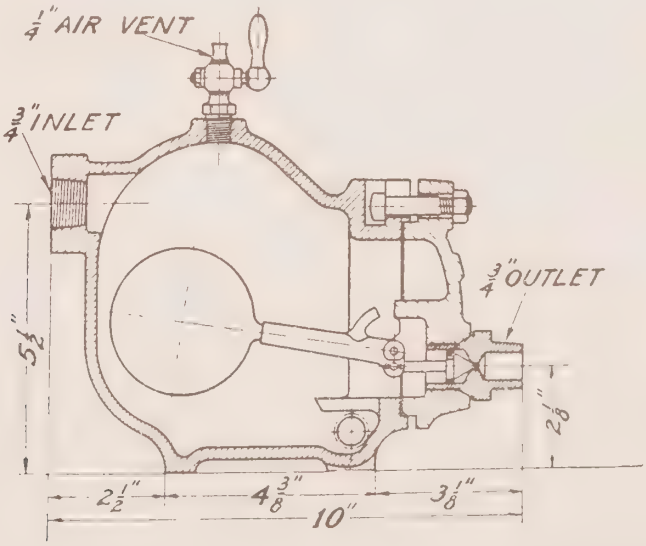


Fig. 3. A typical Float Trap, the valve being operated by a hollow ball and lever.

A vent is placed on the top of the trap to allow for the escape of any air which may collect.

In the operation of traps, care should be taken that the valve is always tight; otherwise, steam will escape through the trap and go to waste.

There should always be a by-pass pipe around the trap, fitted with the necessary valves, so that the trap may be opened and examined at any time. These traps should be connected to pipe lines by drains leading from their lowest points. Very often the traps are used in conjunction with steam separators and connected by a drain leading from the bottom of the separator, where the water settles after being separated from the steam.

Usually these traps are made to discharge into feed water heaters and from there the condensate is returned to the boiler by means of the feed pump.

Fig. 3 illustrates a float trap of the lever type. The rising and falling of the float opens and closes the valve in proportion to the rate of discharge.

Unless float traps are well made and proportioned, there is a danger of considerable steam leakage through the discharge valve, due to unequal expansion of valve and seat and the sticking of moving parts. The discharge from a float trap is usually continuous, since the height of the float, and consequently the area of the outlet, is proportional to the amount of water present. When the trap is working lightly, this adjustment is apt to throttle the area and create such a high velocity of discharge as to cause a rapid wear of valve and seat.

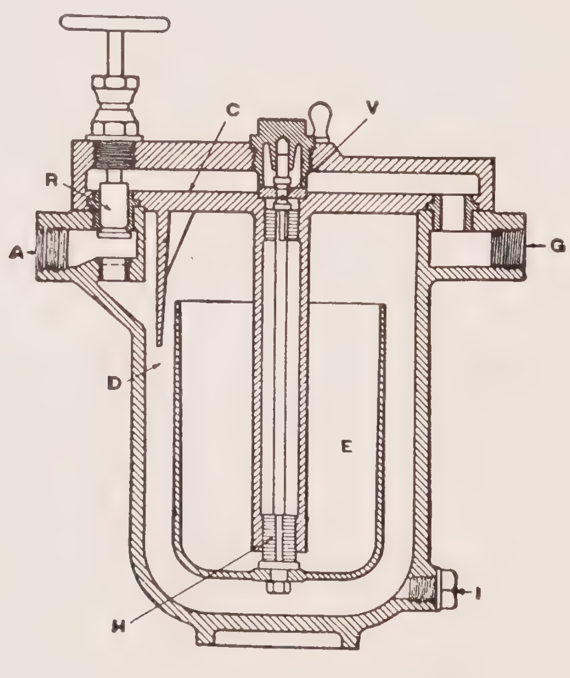


FIG. 4. Bucket Trap.

This defect is more or less evident in all steam traps discharging continuously. For this reason all wearing parts should be accessible and readily replaceable.

A section through one of the many designs in bucket traps, is shown in Fig. 4. The water of condensation enters at A, filling space D between the bucket E and the walls of the trap, which causes the bucket to float. When the bucket floats, valve V is forced against its seat. The water rises until it overflows the edges of the bucket and causes it to sink,

thereby opening valve V. The steam pressure acting on the surface of the water forces it up through ring H and out discharge opening G. When the bucket is emptied, it floats again, closing valve V and the cycle is repeated. The discharge from this type of trap is intermittent.

Dumping Traps

Another type of trap, different in construction but doing the same work, is known as the dumping trap. There are a number of different designs of this type but the principle is the same in all. In the Bundy trap (see Fig. 6) the condensate is received into a hollow spherical shell, while in the Cole and the Morehead and others, a hollow cylinder is used as the receptacle of the condensate.

Dumping traps are frequently used for returning the condensate direct to the boiler without using a boiler feed pump.

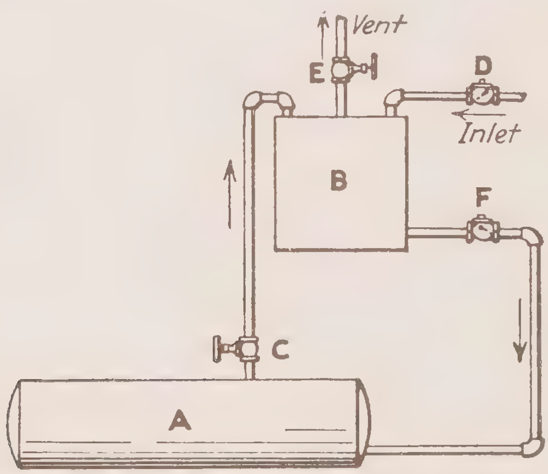


FIG. 5. Diagram showing principle of Return Trap.

Return Traps

Feeding boilers is only one, though perhaps the most important, application of return traps. Among the many other uses are returning condensation of distant buildings to the boiler house, draining vacuum systems, pumping and metering.

All return traps operate on the same principle. From the diagram in Fig. 5 this operating cycle can be easily seen. A is a boiler drum and B a tank 4 to 6 ft. above the water level in the boilerdrum. Condensate returns through the check valve D and into the tank B, valve E in the vent line being open. When tank B is full, valve E is closed and steam valve C is opened, admitting boiler pressure to the space above the water surface in the tank. This forces check valve D to close and check valve F to open, allowing the water in B to flow down into the boiler drum.

To feed a boiler the trap must be above the boiler drum. In actual return traps, valves C and E are automatically operated when the tank becomes full and again when it becomes

empty. Check valves D and F are used with the actual trap as indicated in Fig. 5, though they frequently are not a part of the trap when it is purchased.

All condensate and drains should first be collected in a receiving tank. This gives the condensate a place to flow while the return trap discharges into the boiler. The receiver should be so placed that all the water to be fed to the boiler will drain into it. In most boiler rooms it will be necessary to elevate the water from the receiver tank to the return trap above the boiler. When pressure in the return system is too low to lift the water, a second return trap is installed to raise it to the return trap above the boiler, (see Fig. 6). While the illustration shows the lower trap located in the boiler room, this location is not arbitrary.

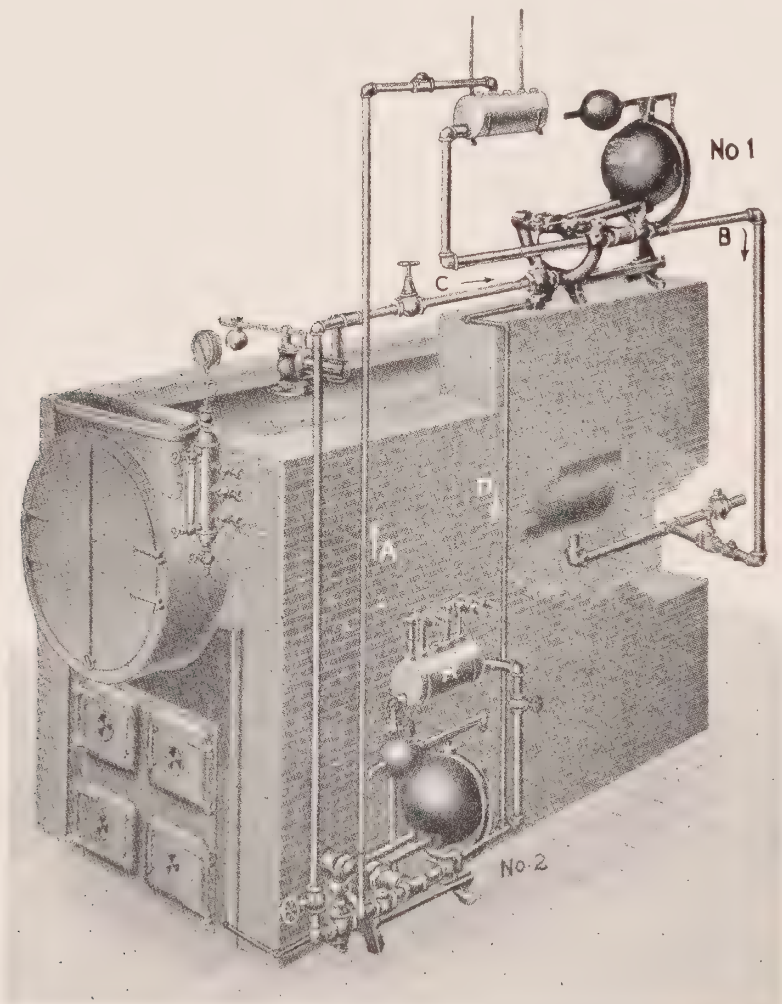


Fig. 6. Method of connecting up Dumping Return Traps to return condensate to boiler. (Note: Lower trap forces water to upper trap which is situated above boiler level.)

Conditions in many plants require the "lifting trap" to be placed hundreds of feet away from the boiler room. In this event the live steam supply is generally taken from a conveniently located line. Where heating coils are scattered, owners can use two or more lifting traps, arranged to empty into one return trap in the boiler room, but the boiler trap must be large enough to accommodate the output from all the lifting traps.

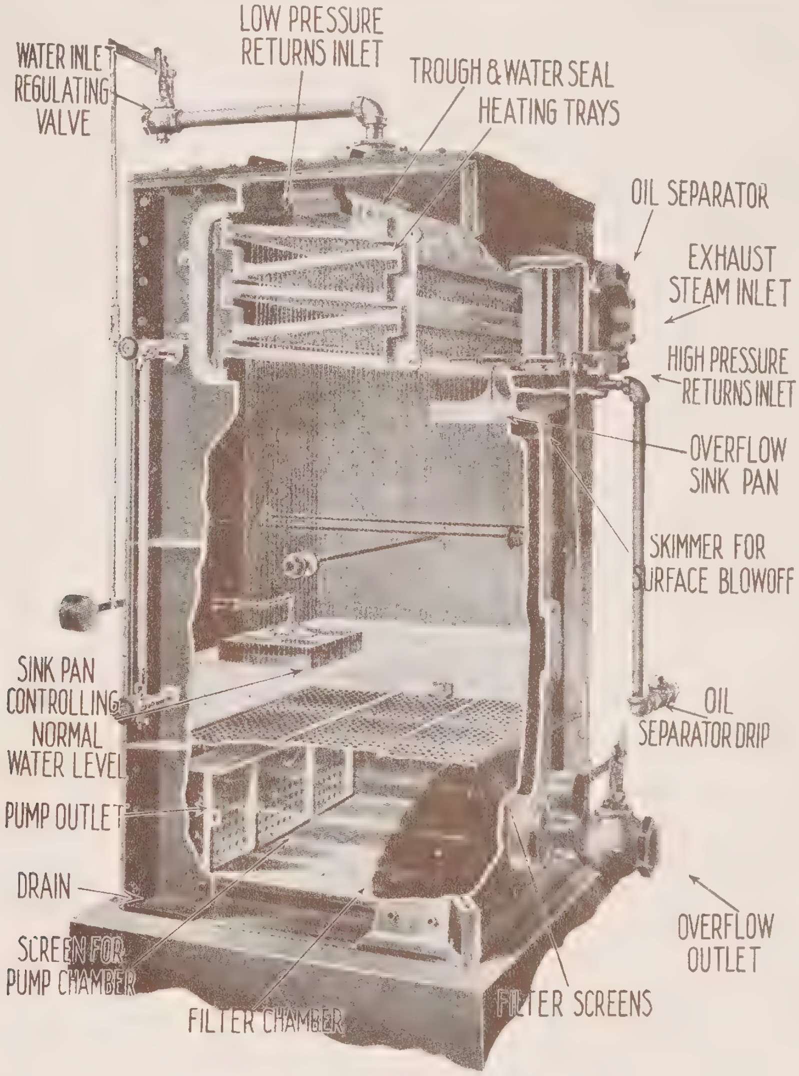


FIG. 7. Open Feed Water Heater.

Open Heaters

In open feed-water heaters the water is heated by direct contact with the steam. This may be accomplished in a variety of ways; by the spray, overflowing trays or an umbrella. If there is a sufficient amount of exhaust steam, the water may be heated to boiling point. However, with ordinary power plant conditions, where the amount of exhaust steam supplied by the auxiliary machinery is but a small percentage of the amount of steam delivered from the boilers, this high temperature is usually not obtained. The open feed-water heater should be placed at least four to five feet above the boiler feed pump, so that the hot water will flow by gravity to the suction valves, whence the water is pumped to the boilers. Most open feed-water heaters are provided with an oil extractor for removing oil from the exhaust steam, so that it may not be sent to the boiler, therefore, in installing an open feed-water heater, sufficient clearance should be left for the removal and cleaning of the filters or trays, as the case may be.

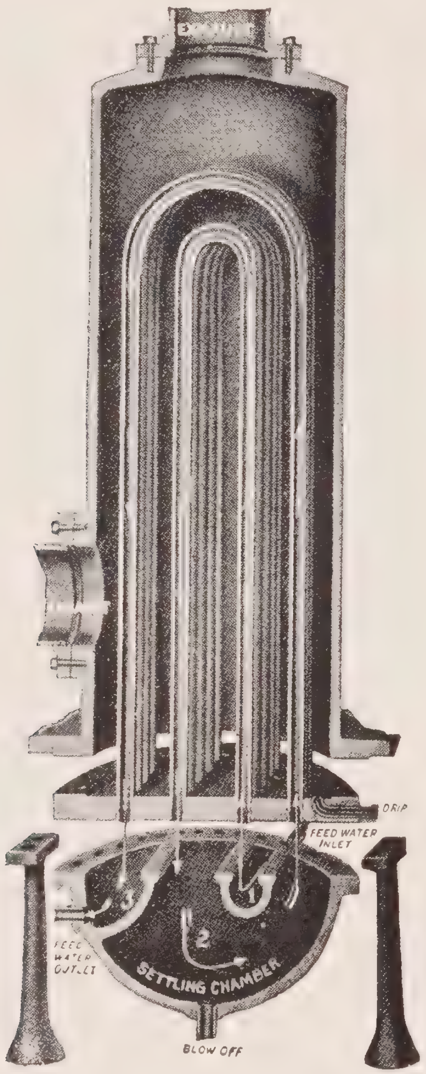


FIG. 8. Closed Feed Water Heater.

From a study of the diagram it is quite apparent that the object of the heater is to receive all the returns from heating system or other sources, and the exhaust from any auxiliary machinery such as feed pumps, fan engine and any other apparatus using steam that, were it not for the heater, would go to waste.

The piping is so arranged that all return water is led in at the top of the heater, where it falls on a series of perforated trays and leaves them in the form of a rain. The exhaust steam that heats the water enters the heater below the trays and travels upward and thus mixes intimately with the descending water, thereby heating it.

There is always a certain amount of loss in return water owing to blowing off of the boiler or any other use of the water, or leaks. It is, therefore, always necessary to provide for makeup water. As can be seen in the diagram, a make-up water pipe enters the top of the heater. On this pipe is a valve, controlled by a lever mechanism which is attached

to a float that floats on the surface of the water in the heater and always keeps it at a constant and predetermined level. To prevent heaters from becoming flooded an overflow is provided.

A filter chamber is provided at the bottom of the heater for the purpose of extracting any impurities from the water before it leaves, near the bottom of the heater, to flow to the suction of the feed pump. An open vent or slow pressure relief valve should always be attached to top of heater to prevent pressure building up in the heater and thus causing an explosion.

Closed Heaters

Closed heaters are designed for carrying the exhaust steam either through the tubes, or surrounding the tubes. In the former, the shell, which is either made of cast iron or riveted steel plates, must be of considerable thickness so as to withstand boiler pressure, provided that the feed pumps discharge through the heater. In the other type of closed heater, the shell may be made of light material, as it withstands no pressure other than that of the exhaust steam.

The advantage of the closed heater over that of the open type is that the feed water can be pumped through it, thus the pump handles cold water, whereas with the open heater, the pumps have to be especially fitted for hot water.

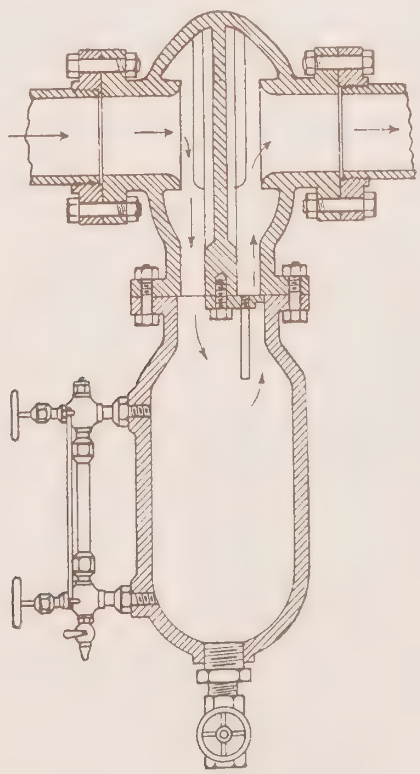


Fig. 9. Steam Separator.

There is also the advantage that the exhaust steam, which may contain considerable oil, does not mix with the feed water and, therefore, there is less danger of oil entering the

boiler. Oil should never be allowed in the boiler as it will collect on the plate, which may as a result become overheated and destroyed. Oil is also liable to cause foaming.

Closed heaters have to be provided with drains and mud blow-offs, the drains to take away water of condensation and oil extracted from the exhaust steam, the mud blow-offs for removing the settlings from the feed water.

Steam Separators

Saturated steam delivered from boilers to pipe line always contain a certain amount of moisture. The percentage of moisture varies greatly, depending upon the design of boiler, also upon the manner in which it is operated, and may vary anywhere from one per cent to twenty per cent, or a rough average of about five per cent.

The amount of moisture present in pipe line is further increased by condensation of the steam, due to faulty insulation.

Moisture has no good qualities and many bad ones. In engines it interferes with proper lubrication, cuts valves and cylinders, absorbs heat by re-evaporating during the expansion of the steam, and if in sufficient quantities, is liable to cause the engine to be wrecked. In steam turbines it cuts the valve nozzles and blades and impedes the velocity of rotor.

Moisture may be eliminated from steam by superheating the steam sufficiently to evaporate all moisture, or, to a certain extent, it may be separated by the use of a steam separator.

The principle of steam separator is that if steam at a high velocity has its direction of travel suddenly changed, the particles of water are by their momentum projected from the steam in a straight line with the direction of original travel, while the steam being of a light nature, is capable of making the turn and separating itself from the water. Any particles of grease, oil or dirt are likewise thrown off by the steam.

From experiments made with different makes of steam separators, it has been proven that moisture of ten per cent or more can be reduced to from two to five per cent.

Fig. 9 shows cross sections of a design of separator, the arrows showing the change in direction of the steam while the water falls to the bottom, from which it should be drained to a steam trap.

Precautions to Avoid Water-Hammer

To avoid trouble from water-hammer action, drains should be provided at the lowest points of every pipe line, and the attendant should invariably open these drains and remove the trapped water as completely as possible, before opening the steam valve. It often happens, particularly when there is a vacuum in the steam pipe, that the condensed water will not run out freely—the vacuum drawing air into the pipe instead of allowing the water to escape. When this occurs the drain should be left open, and after a considerable quantity of air has entered through it, the steam valve may be opened by a mere crack, so as to admit a small amount of steam to warm up the air in the pipe. This operation should be performed

carefully, and only by a man with excellent judgment. When the confined air has been warmed in this way (so that a slight pressure has been produced) a considerable part of the water will run out, if the drain is free. In order to remove the water thoroughly, it may be necessary to repeat this process two or three times. The attendant should not try to hasten the operation, but should take time enough to assure himself that the pipe is actually free from water before opening the steam valve except in the cautious way, and to the limited extent, that we have already described. He should rely upon the expansion of the air to expel the water, instead of trying to force the water out by direct steam pressure.

In many plants the drains operate automatically, discharging into traps. Additional, hand operated drain pipes should then be provided so that the attendants may assure themselves that the automatic draining has been effectively done.

After a pipe has been thoroughly drained, and the attendant has satisfied himself that no more water is present, the stop-valve through which steam is to be admitted may be cautiously opened, the hand wheel being turned only a slight amount at first. In a few

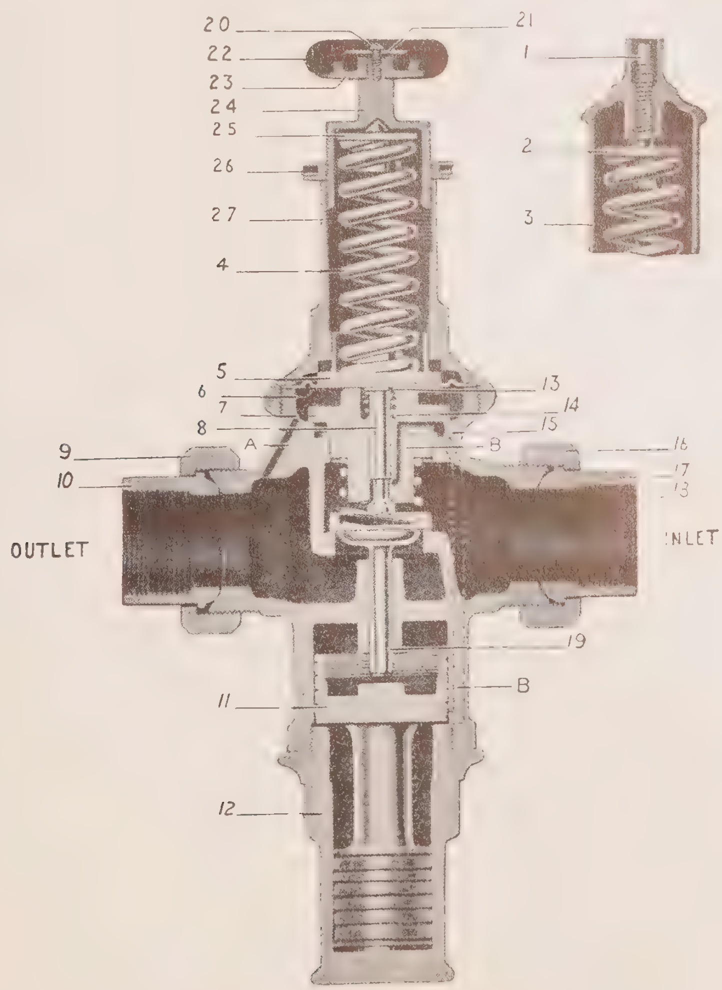


Fig. 10. Pressure Reducing Valve

minutes it may be opened a little more, and when the attendant has satisfied himself that it is quite safe to do so, he may gradually turn the hand wheel to the wide-open position. The valve should not be opened full, however, until the pipe has become well warmed up, and it is important to remember that the act of turning steam into the cold pipe is attended by condensation, so that water will accumulate in the pipe to some extent, in consequence of the admission of the steam.

Pressure Reducing Valves

Conditions sometimes exist in steam plants where it is found necessary to reduce the boiler pressure of the steam before being used. For instance, the auxiliaries of the main power unit may not be designed to operate on as high a pressure as the unit itself, making it necessary to reduce the pressure before it reached them. Also, some heating plants operate with high boiler pressures which must be reduced before reaching the coils. The apparatus used for reducing the pressure is known as the pressure reducing valve. There are several types of this valve in general use.

Fig. 10 shows a spring loaded Morrison type. These reducing valves are controlled by the variation of the reduced pressure acting through the port A, (shown in the cross section) on the diaphragm, 6. This diaphragm is resisted by the spring 4, which is adjusted to the desired pressure. This construction allows the diaphragm to be raised by an increase of the reduced pressure and forced down by the spring 4, when the reduced pressure is decreased. In use the diaphragm is balanced between these two forces, the slightest change of reduced pressure causing a movement of the diaphragm.

The auxiliary valve 8, is held in contact with the diaphragm by the auxiliary valve spring 14, and moves up and down with the diaphragm. As soon as valve 8 is open steam passes through into port B and under piston 11. By raising piston 11, main valve 19 opens against the initial pressure, because the area of valve 19 is only one-half of the area of piston 11, steam is thus admitted to the system. When the pressure on the low pressure side reaches the required point which is determined by the spring 4, the diaphragm is forced upward by the low pressure steam which passes up through port A, to the under side of the diaphragm 6, allowing valve 8, to close, shutting off steam from piston 11. Main valve 19 is now forced to its seat by the initial pressure, shutting off steam from the system and pushing piston 11, down to the bottom of its stroke. Steam beneath piston 11 exhausts freely around the piston (which is fitted loosely for this purpose) and passes off into the low pressure side.

In practice the main valve does not open or close entirely with each slight variation of pressure, but assumes a position which furnishes just sufficient steam to maintain the desired pressure. Piston 11 is fitted with dash pot 12, which prevents chattering or pounding.